HISTORY

OF THE

WATER SUPPLY OF THE WORLD,

ARRANGED IN A COMPREHENSIVE FORM
FROM EMINENT AUTHORITIES,

CONTAINING A DESCRIPTION OF THE VARIOUS METHODS OF WATER SUPPLY, POLLUTION AND PURIFICATION OF WATERS, AND SANITARY EFFECTS, WITH ANALYSES OF POTABLE WATERS,

ALSO

GEOLOGY AND WATER STRATA OF HAMILTON COUNTY, OHIO, STATISTICS OF THE OHIO RIVER, PROPOSED WATER SUPPLY OF CINCINNATI—TOGETHER WITH A NUMBER OF VALUABLE TABLES AND DIAGRAMS.

BY

THOMAS J. BELL,
Assistant Superintendent of the Cincinnati Water-Works.

CINCINNATI:
PETER G. THOMSON, PUBLISHER.
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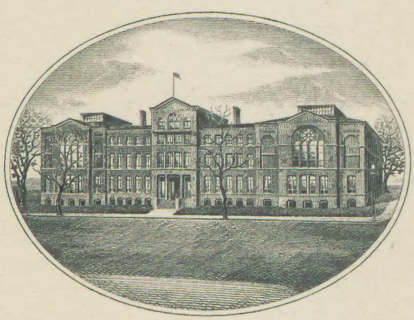

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INTRODUCTION.

The original intention of this work was to arrange a treatise, in the form of a compilation, of general and local information on water supply, in all its bearings, with special reference to Cincinnati, in view of the fact that the question of a new supply would become an important one when the "Markley Farm Project" presented a more tangible form.

As the work progressed, its scope became broader, so much so that the author was induced to depart somewhat from the original idea, and arrange the plan in a more comprehensive form for general use.

To condense a large amount of information in a few pages, so as to make it interesting as well as intelligent, is a work requiring patience and diligence. While the work may be of little service to the profession, it is hoped those connected with water-works and the general reader will find sufficient compensation for the time lost in its perusal.

The authorities quoted are the highest, and the general facts are from the most reliable sources. Considerable space is given to pollution of water, believing it to be the most important question that bears on the subject before us. Water-works officials will find useful information in the work, which is so frequently desired and sometimes difficult to obtain.

Due acknowledgments are made for information derived

from the following works: Rivers Pollution Commission, (London,) 1874; Humber's Water Supply of Cities and Towns; Fanning's Water Supply Engineering, (New York,) 1876; History and Statistics of American Water-Works, by J. James R. Croes, C. E., Engineering News, (New York,) 1881; Hughes' Water-Works, Weale Series; Hydraulic Engineering, Weale Series; Die Städtische Wasserversorgung, Von E. Grahn, (München,) 1878; Practical Hydraulics, by Thomas Box, (London,) 1873; Kirkwood's Filtration of River Waters, (New York,) 1869; Ohio State Geological Works, 1870; U. S. Census Reports, 1881; The National Board of Health Bulletins; The Sanitary Engineer and Engineering News; Catch Water Reservoirs, by C. H. Beloe, London.

January, 1882. T. J. B.

HISTORY OF WATER SUPPLY.

CHAPTER I.

It is an historical fact that the water supply of Rome, during the first century of our era, was so abundant "that whole rivers flowed through the streets of Rome." The quantity was estimated at 375 million gallons per day, an equivalent to 375 gallons for each inhabitant. This supply was conducted to the city through nine costly and marvelous conduits of brick and stone, that tunneled hills and crossed rivers and ravines in the boldest manner, presenting most skillful engineering ability. The number was afterwards increased to fourteen. The principal aqueducts were: Aqua Martia, erected B. C. 431, was 38 miles in length, part of which was composed of 7,000 arches. Aqua Claudia, a subterranean channel for 36¼ miles; 10¾ miles a surface conduit, 3 miles a vaulted tunnel, and 7 miles on lofty arcades, had a capacity for delivering 96 million gallons daily. New Anio was 43 miles in length. Some of these aqueducts were made of three distinct arches, one above the other, that conveyed waters from sources of different elevations.

Constantinople presents remains of the skill possessed by the Romans in the numerous subterraneous reservoirs, covered with stone arcades supported by pillars. Pont du Gard is another relict that supplied the town of Nismes, France. "It consists of 3 tiers of arches, the lowest of 6 arches, supporting 11 of equal span in the center tier, surmounted by 35 of smaller size. Its height is 180 feet, the channel way being 5 feet high by 10 feet wide; the capacity was estimated at 14 million gallons per day."

In Mexico and Peru are found water channels of marvelous length, while India is noted for the numerous impounding reservoirs of wonderful dimensions,—the Poniary reservoir, having an area of 50,000 acres, and banks 50 miles in extent.

While the ancients have left monuments of their skill in gathering and conducting waters, modern science has been, and is, endeavoring to leave a reputation for its devotion to the knowledge of pollution in, and purification of waters required for mankind.

The vast amount of literature devoted to this subject, containing a varied scope of discussions, arguments and analyses, has a tendency to lead one to the conclusion that wholesome water scarcely exists. In fact, the theory advanced by the Massachusetts State Board of Health, in their Fifth Annual Report, is not so premature. They say:

"The time may come when it will be necessary to supply our drinking water from sedulously guarded but limited sources of supply, and to furnish for manufacturing and other uses less pure water. This plan is partly carried out in Paris, and it is the purpose to enlarge it, although much of the water is unfit to drink.

"The injurious character of a water, impregnated with sewage matter, might not be discovered for years. You might go on using it for years and might not be discovered, and you might have some outbreak of disease in the place, which nevertheless might be connected with the use of that sewage water."

The Rivers Pollution Commission of Great Britain struggled with this subject for six years, and at last resolved upon the following classification of potable waters:

Wholesome,	1. Spring water. 2. Deep well water. 3. Upland surface water	very palatable.
Suspicious	4. Stored rain water. 5. Surface water from cultivated lands.	moderately palatable.
Dangerous,	6. River water to which sewage gains access. 7. Shallow well water.	palatable.

The constituent parts of pure water, in volumes, are two parts of hydrogen and one of oxygen, and by weight one part hydrogen and eight parts oxygen. When pure it is transparent, tasteless, inodorous, and colorless, except when seen in considerable depths. But having such high solvent powers and affinity for almost every substance in nature, one can account for suspicions that science places on all waters, for it is never free from impurities. And well it may not, if doctors are to be believed, for they tell us, that chemically pure water is not best for man; that good potable waters have from one to eight grains weight in each gallon of certain impurities diffused through them. Impurities are arranged under the following general heads:

Rain Water—Atmospheric influences.

Spring and Well Water—Mineral properties.

Rivers, Lakes—Vegetable and animal organisms.

But what can we consider good drinking water? Dr. Frankland, of England, has given the following as a minimum limit of mechanical and chemical impurities held in suspension or solution, to be considered bad or polluted liquid:

A. Every liquid which has not been submitted to precipitation, produced by a perfect repose in reservoirs of sufficient dimensions, during a period of at least six hours; or which, having been submitted to precipitation, contains in suspension more than one part by weight of dry organic matter in 100,000 parts of liquid; or which, not having been submitted to precipitation, contains in suspension more than three parts by weight of dry mineral matter, or one part by weight of dry organic matter in 100,000 parts of liquid.

B. Every liquid containing in solution more than two parts by weight of organic carbon, or three parts of organic nitrogen, in 100,000 parts of liquid.

C. Every liquid which, when placed in a white porcelain vessel to the depth of one inch, exhibits under daylight distinct color.

D. Every liquid which contains in solution, in every 100,000

parts by weight, more than two parts of any metal, except calcium magnesium, potassium and sodium.

E. Every liquid which in every 100,000 parts by weight contains in solution, suspension, chemical combination or otherwise, more than 0.5 metallic arsenic.

F. Every liquid which, after the addition of sulphuric acid, contains in every 100,000 parts by weight more than one part of free chlorine.

G. Every liquid which in every 100,000 parts by weight contains more than one part of sulphur, in the state of sulphuretted hydrogen or of a soluble sulphuret.

H. Every liquid having an acidity superior to that produced by adding two parts by weight of hydrochloric acid to 1000 parts of distilled water.

I. Every liquid having an alkalinity greater than that produced by adding one part by weight of caustic soda to 1000 parts of distilled water.

J. Every liquid exhibiting on its surface a film of petroleum, or hydrocarbon, or containing in suspension, in 100,000 parts, more than 0.5 of such oils.

But to arrive at a fair and impartial conclusion, authorities now agree that analyses and investigations must be often, and for a prolonged period of not less than one year. The aim of modern scientists, in their analyses, is to detect the amount of organic (especially sewage) contamination. Dr. Frankland's method is by the estimation of organic carbon and nitrogen, while Wanklyn, Chapman, and Smith reach their conclusions by estimation of nitrogenous organic matter, by breaking up the organic bodies and separating their nitrogen in the form of albuminoid ammonia. Ammonia is the measure of that portion of organic matter not decomposed but in state of or capable of undergoing putrefaction.

The maximum amount of free ammonia permissible in good drinking water is .5 of a grain per 1000 gallons, and of albuminoid ammonia .9 of a grain per 1000 gollons.

Upon the above basis the relative merits of the following waters may be formed:

NUMBER OF GRAINS OF SEWAGE IN EACH THOUSAND GALLONS.

Cities.	Source.	Date.	Authority.	Free Ammonia. Grains.	Albuminoid Ammonia. Grains.	Remarks.
Philadelphia	Schuylkill	1874	Booth & Garrett	1.17	1.76	Fairmount.
"	"	"	"	5.85	5.11	Belmont.
"	"	"	"	7.31	5.12	Flat Rock.
"	"	"	"	1.46	7.31	Perkiomen.
"	"	"	"	17.50	8.75	Spring Garden.
"	Delaware	"	"	25.74	11.70	
London....	Artesian Well	"	"	none	1.75	Bryn Maws.
"	Thames	"	"	1.00	5.31	
Detroit.....	Detroit	1879	Stearns	3.09	7.29	Hydrant.
Hoboken ..	Passaic	1880	Leeds	1.72	19.22	Hydrant water.
Jersey City.	Passaic	"	"	2.96	22.28	"
Patterson ..	Passaic	"	"	1.50	30.90	"
New York..	Croton	"	"	1.60	15.70	"
Brooklyn...	Long Island	"	"	.50	4.80	"
Boston.....	Lake Cochituate	"	"	7.60	35.60	"
Rochester ..	Hemlock Lake	"	"	.90	13.00	"
Philadelphia	Schuylkill	"	"	.60	10.50	"
Wilmington	Delaware	"	"	2.00	17.50	"
Baltimore ..		"	"	2.90	11.70	"
Washington	Potomac	"	"	3.50	15.70	"
Oswego....		"	"	2.00	15.20	"
"	Well	"	"	4.90	12.30	"
Cincinnati...	Ohio River	"	"	6.70	14.00	"
"	"	"	Stuntz	.87	1.40	Markley Farm, best condition.
"	"	"	"	2.45	36.42	Markley Farm, worst condition.
"	"	"	"	3.15	4.37	Dayton Sand B'ch best condition.
"	"	"	"	2.33	14.24	Dayton Sand B'ch worst condition.
"	"	"	"	13.48	11.67	Eden Reservoir, best condition.
"	"	"	"	12.20	42.50	Eden Reservoir, worst condition.
"	"	"	"	2.92	9.10	Pump House, best condition.
"	"	"	"	4.43	79.73	Pump House, worst condition.

The Rivers Pollution Commission value the quality of water by the previous sewage or animal contamination, as they term it. This expression is obtained by taking, as a standard of comparison, the amount of total combined nitrogen (which is

assumed as 10 parts), in solution, in 100,000 parts of average London sewage. The parts of nitrogen obtained, in the form of nitrates, nitrites, and ammonia, less .032 part of 100,000 for that portion in rain, is that nitrogen derived from animal matter. Animal matters dissolved in water, such as those contained in sewage, the contents of privies and cess-pools, or farm-yard manure, undergo oxidation in lakes, rivers and streams very slowly, but, in the pores of an open soil, very rapidly. When this oxidation is complete, they are resolved into mineral compounds; their carbon is converted into carbonic acid; and their hydrogen into water; but their nitrogen is transformed partly into ammonia and chiefly into nitrous and nitric acids. The following table is a compilation of their analyses:

POTABLE WATERS, FROM ANALYSES BY RIVERS POLLUTION COMMISSION, (1874,) (PARTS OF 100,000 PARTS.)

	Organic Carbon.	Organic Nitrogen.	Previous Sewage.
	parts	parts	
Rain-water, collected in leaden gauges	.070	.015	42
" " " from roofs, etc., for domestic use	.257	.080	12031
Dew or hoar frost collected on leaden gauges	.264	.076	1536
Sea-water	.278	.165	103
Upland surface, from non-calcareous strata	.278	.033	0
" " from calcareous strata	.346	.037	33
Land drainage water, from sewage farms	.082	.191	10443
Deep well waters, in the chalk below London clay	.093	.028	797
Spring waters, from the chalk	.044	.010	3511
Bristol, from springs and deep wells	.172	.024	16620
Edinburgh, from springs and streams—water filtered	.145	.026	2020
Glasgow, from Loch Katrine	.204	.017	0
Liverpool, Green Lane well	.020	.020	3840
" Rivington River, gravity supply, unfiltered	.243	.031	0
" " " " " filtered	.210	.029	0
Birmingham, from Bourne River, normal	.211	.039	2480
" " " " in flood	.640	.059	3890
" " " " filtered	.460	.045	2720
" from Aston well	.034	.006	1440
" mixed waters—river and well	.040	.010	1380
London, Thames water from Hampton Grand Junction Works	.246	.033	3270
" " " after subsidence " " "	.262	.042	3270
" " " after filtration " " "	.231	.032	3140
Jacob's Shallow Well, at Sheffield	1.200	.126	590

They consider reasonably safe water, when it is derived from deep wells, (say 100 feet,) or from deep-seated springs, although it contains previous animal sewage, but does not exceed 10,000 parts in 100,000 parts of water. Suspicious or doubtful water is, first, river or flowing water which exhibits any proportion, however small, of previous sewage; and, second, well or spring water containing 10,000 to 20,000 parts. Dangerous water is, first, river or flowing water which exhibits more than 20,000 parts of previous animal contamination; second, river or flow water containing less than 20,000 parts of previous contamination, coming from sewage discharged into it directly, or mingling with it as surface drainage; third, well or deep-seated springs containing more than 20,000 parts, because previous contamination is in direct proportion to the amount of such contamination.

The value of an analysis, sanitarily considered, is questioned. Mr. Simon, medical officer of Her Majesty's Privy Council, testified, before the Royal Commission on Water Supply, on this point, as follows:

"There are dangerous qualities of water supply with regard to which, so far as I know, chemists are totally unable to measure, even to demonstrate the fatal influences that a water may have. A water may be, for instance, capable of spreading the cholera, but chemists be unable to identify the particular contamination which produces that effect. It is, I think, a matter of absolute demonstration that, in the old epidemics, when the south side of London suffered so dreadfully from cholera, the great cause of the immense mortality there was a badness of the water supply then distributed in those districts of London."

Prof. Frankland says:

"That we have no reason to believe that the injurious character of either sewage or of the gases from a drain depends fundamentally upon the quality of that sewage or of that gas. In all probability it far more depends upon the quality of the sewage, namely, what it consists of. Now, what is the nature of the poisonous matter in the

atmosphere or in the sewage? We do not know that, at all; therefore you can not possibly say when that poisonous matter is got rid of from the water or from the air. Chemical analysis can not do it, for its limit is by the power of weighing and measuring. It is not sufficiently advanced, and is one of the poorest things possible to reach those delicate points."

Vital statistics are sources of reliable information; and from them we can learn more of the propagation or dissemination of certain diseases through the water supply, and the relation of water to health. The cholera epidemics of Great Britain exhibit striking examples.

The following are tabulations from the Rivers Pollution Commission Report, 1874:

LONDON.

YEAR.	CHARACTER OF WATER.	MORTALITY.	RATE PER 10,000.
1832	Polluted	5,275	31.4
1849	Very much polluted	14,137	61.8
1854	Less polluted	10,738	42.9
1866	Much less polluted	5,596	18.4

Between the years 1849 and 1854, the water supply was much improved by removal of intakes to purer sources.

The area of intense cholera of 1866 was confined within the limits of the foul or unfiltered water supply by the East London Company; and, when notified and stopped the rate of deaths immediately decreased. It was almost exactly the area of this particular water supply, nearly if not absolutely filling it, and scarcely at all reaching beyond it.

MANCHESTER AND SALFORD.

YEAR.	CHARACTER OF WATER.	NUMBER OF DEATHS.
1832	Used polluted water	890
1849	Used polluted water	1,115
1854	Used pure water	50
1866	Used pure water	88

In 1851 the new supply of unpolluted upland-surface water was introduced in place of shallow wells.

GLASGOW.

YEAR.	CHARACTER OF WATER.	NUMBER DEATHS.	RATE PER 10,000.
1832	Polluted water	2,842	140
1849	Polluted water	3,772	106
1854	Polluted water	3,886	119
1866	Pure water	68	1.6

In 1859 the present source, Loch Katrine, was first used for water supply.

PAISLEY AND CHARLESTON.

YEAR.	CHARACTER OF WATER.	NUMBER OF DEATHS.
1849	Polluted water	182
1854	Polluted water	173
1866	Pure water	7

The testimory Dr. Daniel Richmond, the medical officer of Paisley, before the Rivers Pollution Commission of 1874, in reference to the cholera epidemics, is of sufficient interest to be embodied *verbatim:*

"1. Have you any complaint to make of the water supply? No. The water that we have in Paisley is of a very superior character, and there is an unlimited supply to the whole of the inhabitants. The supply is constant, and I regard that as one of the greatest blessings the people ever received.

"2. Is there any water used which is obtained from wells? None. During the last epidemic of cholera the wells were ordered to be entirely shut up.

"3. When did the last epidemic of cholera occur? Four years ago. But I should say it was not epidemic in Paisley then. It was threatened in 1866.

"4. Had you any cases of cholera then? No. There was a danger felt about it, but I had no fear of it; and I expressed that opinion before the Sanitary Committee, that we should have no attack of cholera, and that the city of Glasgow would not have it.

"5. On what did you found that opinion? Upon the unlimited supply of pure water that we had, and on the supply of pure water that Glasgow had obtained from Loch Katrine.

"6. Was your prediction fulfilled in both cases? Yes.

"7. When had you cholera last in Paisley? Was it in 1854? In 1854.

"8. Had you an attack of cholera in 1849? Yes. A very sharp attack.

"9. What was the state of the water supply in 1849? In 1848 and 1849 the town was but partially supplied with water, and some of the large suburbs, such as Charleston, were not supplied with the town's water. Charleston was supplied with water from wells. There was one well that belonged to Baille Smith, which supplied a large quadrangle of buildings; that well was at the bottom of an incline, surmounted by buildings on all sides except one. Those wells took a supply from the surface. They were surrounded by dung-pits, and the wells imbibed the impurities of the dung-pits. I took occasion to warn the people of the district not to use water from the wells, but to get the town's water. I recommended the authorities to open pipes connected with the town's water, and to supply Charleston with pure water; and very soon after that was done the cholera disappeared from that district. At the last threatened visitation of cholera, in 1866, the Sanitary Committee took the precaution to remove all the handles from the pumps, and they had the wells shut up.

"10. Do you think there is a direct connection between the water supplied to a town and the propagation of cholera? I believe that there is a very intimate connection between the use of impure water and the propagation of cholora; and the proper antidote to that is a free and unrestricted supply of pure water."

In Calcutta the yearly death rates from cholera averaged nearly 4,000 from 1841 to 1870. When water-works were introduced the rate of deaths were:

1870	1,560	1872	1,068
1871	790	1873	1,134

The famous Broad Street pump, in London, in 1848, killed 500 persons in a single week.

In 1866 many deaths occurred from the use of water from a famous pump in Brooklyn. All trouble was brought to an end when the health officers removed the handle.

Typhoid fever and diarrhea are universally traced to impure

water, and numerous examples can be given that were directly due to this cause. The enterprising town of Rugby, on the Cincinnati Southern Railroad, furnished us with a case of this nature. In Millbank Prison, England, typhoid fever was especially fatal until the year 1854, when the supply was taken from an artesian well in Trafalgar Square, instead of the Thames; and immediately thereafter, and up to April, 1872, a period of eighteen years, there have been only three deaths from typhoid fever.

CHAPTER II.

RIVER POLLUTION.

This subject is possibly most interesting to Cincinnati, because of its direct application to our source. River water is next to the most suspicious of waters, and the character is the bone of contention among scientists. Just how far and how much sewage may be admitted, and what influences are exerted to destroy it, are interesting discussions, part of which we have quoted.

The Rivers Pollution Commission of Great Britain arrived at the conclusion "that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation." And a direct contradiction of the statement by the eminent physician, Dr. Letheby, medical officer to corporation of London, "that if sewage matter be mixed with twenty times its bulk of ordinary river water, and flow a dozen miles, there is not a particle of that sewage to be discovered by chemical means."

The experiments of this commission show "that scarcely two-thirds of the sewage was destroyed in a flow of 168 miles, at the rate of one mile per hour, or after the lapse of a week."

Investigations of the Rivers Pollution Commission on Sewage Pollution are as follows:

REDUCTION BY OXIDATION IN RUNNING WATER.

NAME OF RIVER.	LENGTH OF FLOW IN MILES.	TEMPERATURE. CENTIGRADE.	PERCENTAGE OF REDUCTION OF ORGANIC ELEMENT.	
			IN ORG CARBON.	IN ORG. NITROGEN
Irwell.........	11	6 to 8	4.5	0
"	11	12	0	11.8
"	11	17	29.6	0
Mersey........	13	4 to 4.8	20.8	17.9
Darwin	13	6.8 to 10	0	13.2

REDUCTION OF SEWAGE BY AERATION.

One volume of filtered London sewage mixed with nine volumes of water, the mixture contained .267 organic carbon and .081 organic nitrogen. After agitation and freely exposed to the air and light every day, and being syphoned, in a slender stream, from one vessel to another, the result, after 96 hours, was .250 organic carbon, and .058 organic nitrogen; and, after 196 hours' test, was .2 organic carbon, and .054 organic nitrogen. Temperature, 20° centigrade.

The above results would correspond to a flow of 96 miles, at rate of one mile per hour, with a reduction in per cent of 6.4 organic carbon, and 28.4 organic nitrogen; or a flow of 192 miles, at rate of one mile per hour, with a reduction in per cent of 25.1 organic carbon, and 33.3 organic nitrogen.

Test of a mixture of fresh sewage with Thames water, and enclosed in stopped bottles, and opened to air at following intervals, with results opposite the respective periods:

	PER CENT OF SEWAGE DESTROYED.
1. Period of 24 hours..........................	6.8
2. Period of 24 hours..........................	8.9
3. Period of 48 hours..........................	14.3
4. Period of 24 hours..........................	5.4
5. Period of 24 hours..........................	5.8
6. Period of 24 hours..........................	2.1
Total..............................	43.3

Dissolved oxygen contained in the enclosed water was determined by boiling off the dissolved gases.

REDUCTION OF URINE BY AERATION.

Urine, in proportion of one gallon (imperial) to 3,077 gallons of water, exposed to the air and briskly agitated:

DATE.	PARTS IN 100,000 PARTS. ORGANIC CARBON.	ORGANIC NITROGEN.
Feb. 17, 1874,	.282	.243
" 18, "	.298	.251
" 19, "	.244	.255
" 24, "	.225	.253
" 25, "	.214	.259
" 28, "	.214	.276

Results show that fresh urine with a large volume of water is, under atmospheric influences, more permanent and indestructible than sewage.

The agents of destruction of sewage are:

Infusorial animals.	Chemical Oxidation.
Aquatic plants.	Dilution.
Fish.	Deposition.

Sir Benjamin Brodie, in his evidence before a former River Pollution Commission, stated: "That it was simply impossible that the oxidizing power acting on sewage running in mixture with water over a distance of any length is sufficient to remove its noxious quality; that the oxygen in the water and on its surface does not exercise any rapidly oxidizing power on organic matter." He believed "that an infinitesimally small quantity of decayed matter is able to produce an injurious effect upon health; that if a large proportion of organic matter were removed by oxidation, the quantity left might be sufficient to be injurious to health. To destroy organic matter the most powerful oxidizing agents are required. We must boil it with nitric acid and chloric acid and the most perfect chemical agents. To think to get rid of organic matter by exposure to the air for a short time is absurd."

Prof. Frankland, one of the Rivers Pollution Commission of 1874, says:

"That I should rely upon dilution quite as much and more than upon the destruction of injurious matter; that the flow of a river has a most natural influence in the removal of subsidence of a large proportion of the suspended impurities both organic and mineral, *especially if the flow be sluggish in places.*"

Prof. Brodie stated:

"There are causes operating, as we all know, to destroy the sewage which, to a certain extent, will effect that end; but the question, as I understand it, is, whether those causes are really adequate to destroy the sewage, not partially but absolutely and entirely, during a given course of the river? *I do not think, in the present state of our knowledge, to pronounce an absolute opinion upon that point.* But if you ask whether it is wise to drink water into which you have put sewage, knowing that you have no means of getting that sewage out of it, that is a question which any one can answer for himself, assuming always the injurious character of sewage."

The fifth annual report of the Board of Health of Massachusetts (1875), contains the following, on the effects of oxidation, dilution, and deposition:

"*Oxidation.*—Although it is not practical, in the case of a running stream like the Merrimack, to trace the progress of the destruction of the organic material by oxidation, yet there is no doubt that a certain amount is so destroyed. The presence of nitrogen in the form of nitrites and nitrates is mainly due to the oxidation of nitrogenous organic material. In the last report of the Board, the reasons are given which lead to the belief that the effects of oxidation have been overrated, although they are not, on the other hand, to be depreciated.

"*Deposition.*—Much waste material, thrown into rivers, is made up wholly or in part of substances insoluble in water. A portion, and a very considerable portion, even in a running stream is deposited upon the bottom or stranded upon the banks. At the time of spring freshets much that during the summer may have been deposited at one part of the stream, in the bed or on the banks, is washed up again, and mingling with the earthy materials, held in suspension, is swept onward to the sea or enveloped in the earthy matter, especially if this be of a clayey nature, is deposited lower down the stream. These spring freshets are relied upon for cleansing banks used for infiltration.

"*Dilution.*—By far the most important reason of the apparent disappearance of sewage and other waste material, is the fact that the amount of solid matter is so small compared with the volume of water into which it is thrown, that it is disseminated through the mass and thus lost to observation, and in many cases to chemical test.

"Analyses of water, below and above Lawrence and Lowell, showed no increase in chlorine. The substance can not escape from the water in gaseous form, nor does it deposit in insoluble combination, yet first inspection would lead to a conclusion that no real increase existed. The facts are that the reduction was due to dilution, and not to any destruction or decomposition. Much depends of course upon the size of the stream into which the refuse is thrown. Thus, while into the Merrimack at Lowell, even during the minimum summer flow of 2,100 cubic feet per second, it would be necessary to throw more than 100 tons of solid matter daily in order to increase the amount in the water by one grain to the gallon; another and smaller stream might be hopelessly fouled by a single factory."

The effects of dilution are shown in the analysis of the Schuylkill River—there being less sewage at Fairmount Dam, the nearest to the outlet, than any point above. It is estimated that 300,000 inhabitants, exclusive of those in Philadelphia, live within the water-shed of this river, less than 150 miles above Philadelphia, the undiluted sewage from these persons amounting annually to 150,000 tons. In addition to this pollution 15,000,000 gallons daily flow from 115 establishments located on the banks, not considering the 57 collieries and 76 anthracite furnaces. Yet with all this contamination the water at Fairmount, chemically considered, is as pure as most sources. The chemists in their report say: "Having now shown that the Schuylkill water is about as good a water as we might wish to find for a large city in its mineral and organic content.

"Since the present water is good enough, we may keep it so, and even improve it by a system of sewage gradually extended up both sides of the river, especially the left bank, above the influence of Monayunk, and by procuring sufficient legislative power to control the escape of sewage or possibly injurious manufacturing residue. The long line of many miles would tend greatly to the purification of the water by aeration, deposition, or abstraction of possibly injurious substances from the water by the time it reached within using distance of the city."

The increase of solid matter in the Schuylkill has been as follows:

1842, 4,421 grains in 1,000 gallons.
1854, 6,109 grains in 1,000 gallons.
1862, 7,040 grains in 1,000 gallons.
1875, 8,139 grains in 1,000 gallons.

The recent analysis by Prof. Stuntz of the Ohio River, also shows the effects of dilution. (The results express the number of pounds of sewage in one million gallons.)

	GENERAL CONDITION LBS.	WORST CONDITION LBS.	GENERAL AVERAGE LBS.
At pumping works,	1.81	11.39	4.18
At mouth Eggleston Avenue sewer,	4.41	17.91	11.16
At Storrs and Lower River,	1.96	10.00	5.94

Although increased by the whole sewage of the city in addition to Licking River, Covington, and steamboat contamination, the proportion of sewage at Storrs in its worst condition is chemically shown to be little better than at the pumping works.

THAMES RIVER.

Although the water of the Thames has been submitted to analyses by different chemists, on many hundred occasions, no constituent which could be pronounced noxious, has been detected; but the history of the water traced in the inorganic constituents above referred to, always reveals that which is, indeed, well known to be the fact—its previous contamination with sewage or animal matters—(Rivers Pollution Commission, 1874.)

The area of water-shed drainage of the Thames above pumping station is 3,675 square miles, the minimum summer flow of 350 millions of gallons daily. There are one million persons above the intakes of pumping works. The whole river and its principal tributaries are under strictest sanitary regulation, which the government is able to enforce, notwithstanding a great mass of sewage is poured into the stream.

The Rivers Pollution Commission, of 1874, sum up their investigation of the Thames and Lea Rivers as follows:

"1st. That the river receives the sewage from a large number of towns and other inhabited places, the washings of a large cultivated land, and the filthy discharge from many industrial processes and manufactures.

"2d. That the water is used for bathing, washing of sheep and cattle, and dirty linen and putrid carcasses of animals float upon its surface.

"3d. That it is the common water way for a large amount of dangerous polluting matter, etc.

"4th. That in time of flood a large proportion, both of the suspended and dissolved filth, is conveyed down to the intakes, and in ordinary weather considerable portion of soluble organic matter makes its way to the pumping works, and is still present in the water distributed *to the consumers.*

"5th. That the water is, nevertheless, when efficiently filtered, free from any offensive taste or odor.

"6th. That, notwithstanding the application of partial remedies for sewage pollution, at Banbury, Eton, and Windsor, and the great care exercised by most of the companies in the storage and filtration of the water, the organic pollution contained in the Thames water delivered in London, though subject to fluctuations from the greater or less prevalence of floods, does not diminish. The proportion of organic impurity present in Thames water, as delivered in London, was:

"In 1868, 1,000	In 1870, 795	In 1872, 1,243
"In 1869, 1,016	In 1871, 928	In 1873, 917

"7th. That there is no hope of this disgusting state of the river being so far remedied as to preclude the presence of animal and other offensive matters, even in the filtered Thames water as delivered in the metropolis.

"8th. That the Thames should, therefore, as early as possible, be abandoned as a source of water for domestic use.

"9th. That the temperature of the water drawn from the company's mains is liable to excessive fluctuations, being near the freezing point in winter and so warm in summer as to be vapid and unpalatable."

The Lea River is also condemned as a source of water supply.

Prof. Chandler, of New York, quotes the authority of eminent scientists, who say the Thames, a short distance above London, is wholesome, palatable, and agreeable, and safe for

domestic use, notwithstanding the large amount of sewage (the number of grains per gallon being three times that of the Schuylkill), although controlled by strict governmental laws.

QUALITY OF POLLUTION.

Scientists tell us that it is not so much the quantity as the quality of the sewage:

"It is true a large amount of refuse material is of such character as to be, except in excessive quantities, of no appreciable influence on the human system; the addition of the inorganic compounds of lime, soda, potash, etc., would have no deleterious effect; in fact, although the lime compounds increase the hardness of water, and make it less desirable for washing, the presence of a moderate amount of mineral substance makes the water more palatable and very probably more wholesome.

"Then, in case of many waste liquors, which appear to be very offensive, the matter which really could be regarded as injurious is comparatively small in amount. If we consider the character of the substances discharged by different manufacturing establishments, we shall find them very different. Some of them are such as to be universally regarded as unfit to admit to any stream; those, for instance, containing lead, arsenic, etc.; others, such as salts of iron, are scarcely regarded as injurious; thus, the discharge of sulphate of iron (copperas) into a stream already polluted with sewage matter, might, within certain limits, be of positive advantage. Again, in the case of some of the vegetable dye-stuffs, the weak-spent dye liquors, although they communicate a very foul appearance to the water for some distance, yet contain a comparatively small amount of solid matter, and, if discharged into a stream of considerable size, as soon as disseminated through it, are diluted to a very great extent.

"Different in character, however, from much of the refuse of manufacturing establishments is the sewage coming from dwellings, or the sewage (in its more restricted sense of excremental matter from animal sources) which comes from our manufactories. In fact, this foul material, coming from establishments employing a large number of operators, is likely, in many cases, to have a more injurious effect

upon the stream into which it is thrown than refuse from the manufacturing operations. There are, however, some branches of industry which discharge refuse material offensive and dangerous to health. Such material is discharged from tanneries, wool-pulling and hide-dressing establishments, slaughter-houses and rendering-houses. 'Too much stress can not be laid upon the importance of preventing the discharge of such refuse.' "—(Prof. Nichols, in Fifth Annual Report of Massachussets State Board of Health.)

"The discharge of gas works is known to kill fish and destroy lower forms of animal life, which are important agents in preserving the purity of fresh water.

"One would not assert that the drainage of a single house would contaminate the water of a large river like the Merrimack so as to make it unfit for domestic use, yet we must beware how we depreciate the effect of sewage matter, even in a large stream."—(Prof. Nichols, in Fifth Annual Report of Massachusetts State Board of Health, 1875.)

"With small amount of sewage the chances are favorable for the action of atmospheric influences, and particles of undecomposed material-propagating disease are rendered proportionally small, owing to the great dilution.

"A minute quantity may do much harm, because it is now generally believed, that it may hold the specific thing that propagates specific diseases.

"Rice water evacuations, of a cholera patient, however much diluted, still remains in liquid, although chemical test fails to detect it.

"The carcass of a dead animal, thrown into a river or pond, and confined there, so as not to be borne off bodily, gradually wastes away, and, in a longer or shorter time, the main part of the carcass has disappeared. What has become of it? A part has been converted into gaseous products of decomposition, as the offensive odors observed during the decay will testify; but another portion has been carried off by the stream as soluble nitrogenous organic matter. This nitrogenous matter would be detected a short distance away, with greater or less ease, according to the volume of water present; but in a stream of large size, or in a lake at no very great distance from the source of contamination, it would be impossible to discover any offensive matter. There is a limit to the delicacy of our tests: there is a point beyond which, at the present, we are not able to go. At the present time, a chemical analysis alone is not sufficient to determine

the desirability of a given water-supply."—(Rivers Pollution Commission, 1874.)

"The action of a float, upon or near the surface of the water, is no indication of the movement, back and forth, of the sewage in suspension. Portions of fresh sewage, it is true, will float, but after maceration the sewage has a specific gravity of about 1.325, and will sink, in still water, or very slow currents, at the rate of one foot per minute; but in a current of 170 feet a minute, it will not sink, but remain in suspension."—(J. W. Adams, C. E., Water Supply Commission of Philadelphia, 1874.)

"This evidence, taken in connection with our own investigations, appear to us, conclusively, to prove:

"1st. That there is, at certain times, in human excreta, some material capable of producing disease, of a very fatal character, in human subjects.

"2d. That this morbific matter can be detected only by its specific action upon human subject, and can not be distinguished, either by chemical or microscopical analysis, even in the concentrated excreta, much less in water mixed with the excreta.

"3d. That, inasmuch as the organic matters of sewage are oxidized and destroyed with extreme slowness in running water, there is great probability that morbific matter will escape destruction and be conveyed to great distances in rivers and streams."—(Rivers Pollution Commission, 1874.)

"Carbonates of calcium and lime produce temporary hardness; while sulphate of lime and calcium and salts of magnesium produce permanent hardness.

"Temporary hardness is objectionable for culinary and manufacturing purposes, and excessive hardness is productive of disease known as gravel. Magnesium salts are especially objectionable, because they cause diarrhœa and dyspepsia. Goitre, or swelling of the glands and cretinism, a kind of insanity, are charged to this impurity.

"Frequently, the water happens to be a little off color, especially after a heavy storm, and the consumers get an idea that the water is poisoned, and no amount of re-assuring will prove the reverse. Such cases occurred in New Yory City, once or twice, during the late war with the South. A little investigation will show the absurdity of such a thing.

"One-sixteenth of a grain of strychnine is necessary to poison a

person. It would, therefore, require three and one-half tons of strychnine to have poisoned the Croton water effectually—a quantity not to be had in the world, and to procure it would take about three years.

"If arsenic was desirable, two grains for each person would be required, or 114 tons for the whole population of the city at that time. Living animals, when seen under the microscope, are very formidable in appearance and frightful in motion, yet they are not objectionable. They only inhabit very pure water. It sometimes happens, owing, perhaps, to some peculiarity of the season, that these little animals multiply to such an extent as to produce serious annoyance.

"It is stated that one-sixth of the deaths in Iceland are caused by little animals being taken into the system. Young leeches, contained in drinking water, sometimes fix themselves on the pharanx. In Algiers, 400 French soldiers were sick at one time from this cause." —(From Prof. Foote's lecture.)

CONTAMINATION OF WATER SUPPLY.

Boston water has become quite offensive from vegetable fermentation, some say, although others attribute it to dead fish, eels, and animal organisms, and, later, to a green moss. The water tastes, at times, like cucumbers. The present trouble is traced to the new "Sudbury" supply. The older source, Lake Cochituate, is, however, contaminated by drainage from the town of Natick, through Pegan Pond.

Croton water (New York supply) has, at times, suffered from dead fish and decayed leaves.

Hartford, Yonkers, Poughkeepsie, and Albany report the presence of miscroscopic plants and animals in their water, and these organisms indicate stagnation. "Any undue preponderance of animal or vegetable life lead to the propagation of new forms of life dangerous to health."

Springfield (Massachusetts) water tastes, at times, like green corn; while Cambridge is contaminated by the drainage of meadows.

Mr. G. W. Carpenter, Superintendent of Albany Water-Works, reports:

"There are two distinct causes (each imparting to the water an odor and taste peculiar to itself) that have affected our reservoirs, at different periods, during the last few years: the one giving to the water the odor and taste of fish, the other imparting to it a musty odor and taste sometimes detected in dead wood. In the former, it is extremely difficult to satisfy consumers that the impurities are not due solely to fish in the reservoir, while in the latter they are equally confident that the reservoirs are little less than stagnant ponds."

The latter is sometimes exceedingly offensive and similar to sulphuretted hydrogen gas. In 1875 he again reports: "That all impounded waters in this section of the country are liable to become impure; that while the impurities have been traced to lower forms of animal organisms, little is known of the condition that favor their growth; that the germs of the organism probably come from the atmosphere."

Chicago will be compelled to move her crib further into the lake, now two miles from shore, to get beyond the limits of the Chicago River sewage.

St. Louis, like Cincinnati, has outgrown its water system (established in 1872 at a cost of five millions,) and is obliged to drink muddy water.

Cleveland extended its aqueduct in 1872, 1¼ miles into the lake in order to escape shore water.

Detroit, after considerable discussion, removed their source of supply three miles above the city, and constructed new works in preference to expending more money on the old works.

Rochester, N. Y., expended 4½ millions for bringing the water of Hemlock Lake thirty miles to the city.

Baltimore celebrated only last October the opening of their new aqueduct, conveying the waters of Gunpowder River 7 miles in distance, at a cost of over four millions.

Indianapolis has been compelled to erect new works owing to the contamination of the present source.

CHAPTER III.

PURIFICATION OF WATERS.

The Rivers Pollution Commission of 1874, says, as regards filtration: "No process has yet been devised for cleaning surface water once contaminated with sewage, so as to make it fit for drinking." Others say it is not safe to trust to dilution, storage, agitation, or filtration for periods of time, for the complete removal from water of disease-producing elements whatever they may be.

Dr. Frankland states:

"I believe the noxious parts in sewage is that which is held in mechanical suspension, not held in solution. I would not say it is impossible to remove it, but no system of filtration will secure its removal. There are only two processes by which it can be effectually removed—one by boiling for a long time, and the other by distillation."

The methods adopted for filtration of water are:

"1. Infiltration—by intercepting underground currents through natural formations of beds or banks of water-courses.

"2. Filtration—mechanically by artificial beds of sand, gravel, etc., chemically by charcoal, iron, etc.

"3. Subsidence—clarification by deposition; storage reservoirs.

"4. Aeration—spontaneous purification by oxidation.

"5. Covered reservoirs—to prevent atmospheric influences.

"6. Precipitation of carbonates—Clark's System."

The infiltration system is resorted to where natural means for permeation are found; the galleries for intercepting the water being constructed in the sand or gravel banks or bed.

The clarification, however, is necessarily restricted, owing to the general high rate of filtration.

Lowell, Mass., has a gallery in the gravel banks of the Merrimack River, 1,300 feet in length, 8 feet by 8 feet, the bottom

8 feet below the river bed. The capacity is six million gallons, and rate of flow 150 gallons per square foot in twenty-four hours.

Lawrence, Mass., has a similar gallery.

Brookline's (Mass.) gallery is 762 feet in length; 6 feet below the river bed. Rate of flow is 490 feet per square foot.

Newark, N. J., tried the experiment of driven wells. They drove sixty-three-inch tubes 28 feet apart, 40 feet deep, into the bank of the Passaic, three hundred feet from the shore line. The tubes were attached to three lines of suction pipes, and the latter united in one twenty-four-inch main for the supply of their five million pump. As their expectations as to the quality and quantity of water were not realized, a well was substituted.

Columbus, O., has a gallery under the Scioto River, 600 feet in length, with a capacity of eight millions daily.

Toronto, Canada, has a basin excavated in an island of Lake Huron, opposite the city, 13½ feet below low water, and 3,090 feet in length; the rate of flow is 52 imperial gallons per square foot for twenty-four hours.

Lyons, France, has two covered galleries along the banks of the Rhone; the area of bottoms 17,200 square feet; capacity six millions, and rate of flow at lowest stage 100 gallons per square foot.

Toulouse, France, has three covered galleries along the banks of the Garonne River. The last gallery constructed is 1,180 feet long; capacity, two and a half millions; rate of flow, 228 gallons per square foot of bottom area.

Perth, Scotland, has a gallery in an island of the River Tay, 300 feet long, 4 feet wide by 8 feet high, 2½ feet below the surface of the river; rate of flow, 182 gallons per square foot per diem.

Genoa, Italy, has a gallery in the valley of the northern slope of the Mantine Alps, 1,181 feet above the sea level. It is 1,780 feet long, 5 feet wide and 7 to 8 feet high, and extends, in part, beneath the bed of the river Scrivia, transversely from side to side, and in part along the bank. It has a delivery of 6,412 gallons for twenty-four hours per lineal foot.

The city of Glasgow made two failures in attempting to fur-

nish a supply by this system. The first experiment was the construction of a reservoir on the northern bank of the Clyde, below the level of the river. Beneath the bottom of the reservoir was thirty-two-feet cylindrical tunnels made of wedged-shape bricks without mortar. The failure was due to the inability to keep the interstices free from the deposit of impurities. In the second plan, they excavated shallow wells, 10 feet in diameter, 6 feet deep, and 20 feet apart, in the stratum of sand adjacent to the river. The wells were connected by pipes. The scheme was a worse failure than the first one.

It often happens, as in the case of Waltham, Massachusetts, in locating these galleries, that spring water is intercepted in place of the desired water of the flowing stream. The difference in temperature and increased hardness of the spring water, determine the class of water.

FILTRATION

is the artificial method of clarification by mechanical and chemical means. By the mechanical system heavier impurities are held in suspense by percolation of water through carefully prepared beds of sand, gravel, coke, shells, and like substances.

The total area of the London filter beds in 1874 was 68 acres, and rate of filtration per hour in inches and depth of water, or head on beds, were:

	RATE.	DEPTH.
Lambeth Works	10 inches.	7 feet.
Southwark & Vauxhall	4 "	4 "
Grand Junction	3 "	4 "
West Middlesex	4 "	3 "
Chelsea	6 "	5 "
New River	4½ "	5 "
East London	3 "	5 "

The efficiency of filtration is inversely to rate of flow. Humber says:

"It is now generally admitted that filtration through sand, to be effective, should not proceed at a higher rate than 6 inches of descent

per hour; or, in other words, there should be at least 1½ square yards of filtering area for each 1,000 gallons per day. This is, of course, exclusive of reserve area, which will be necessary to permit of at least one bed being cleansed while sufficient area remains in operation in the other beds."

The maintenance of these beds enhance the cost of supplying water, because they must be cleansed frequently—in some cases once a week. The regulation and control of the water consumption is an important consideration, that the rate of increase will be proportioned to the growth of the city; and not, as in this country, an unaccountable rapid increase due to the profligate use of water that makes filtration impossible. Over eleven-twelfths of the water supplied to London is filtered with the following efficiency:

	BEFORE FILTRATION.		AFTER FILTRATION.	
	ORGANIC CARBON.	ORGANIC NITROGEN.	ORGANIC CARBON.	ORGANIC NITROGEN.
	In parts of 100,000.	In parts of 100,000.	In parts of 100,000.	In parts of 100,000.
West Middlesex Works	.209	.071	.198	.043
Grand Junction Works	.262	.042	.231	.032
Southwark & Vauxhall, Hampton Works.	.321	.063	.273	.042
" " Battersea "	.239	.047	.226	.035
Lambeth Works	.273	.067	.258	.038
Chelsea Works	.325	.076	.258	.032
New River, Lea River	.287	.067		
" New River	.375	.059	.227	.043
" "	.350	.084	.246	.042
East London Co., Lea Water	.363	.082		
" Waltham St. Res	.481	.092	.305	.041
" Thames Water			.159	.030

Dimensions of filter beds for given volumes (from Fanning):

For	1	million	gallons	per diem	3	beds	60 feet × 100 feet.
For	2	"	"	"	3	"	80 " × 150 "
For	3	"	"	"	3	"	100 " × 180 "
For	4½	"	"	"	4	"	100 " × 180 "
For	6	"	"	"	4	"	100 " × 240 "
For	8	"	"	"	4	"	120 " × 270 "
For	10	"	"	"	5	"	120 " × 270 "

Analysis of sand from filter beds (in 100,000 parts)

	ORGANIC MATTER.	ORGANIC CARBON.	ORGANIC NITROGEN.
As removed from filter bed, unwashed....	1523.40	314.160	38.674
After washing..................................	804.41	94.921	16.973

It can not be doubted that a small amount of organic matter undergoes oxidation and destruction during the passage of the water through the sand; but, independent of this, it appears, from the above analytical numbers, that one ton of dry sand, washed after previous use, is capable of removing from water and retaining 16.1 lbs. of peaty matter.

Chemical filtration may be arranged under the following heads:

1. By use of alum and borax to reduce turbidity.

2. Dr. Gunning's experiment of the waters of the River Maas, by reducing the turbidity with .032 gramme of perchloride of iron into one litre of water.

3. Dr. Bischoff's (Jr.) process of removing organic matter by spongy iron, prepared by heating hydrated oxide of iron with carbon.

4. Spencer's process of sand filtration with crushed grains of a carbide of iron. The carbide, it is claimed, does not require frequent removal.

5. Sheet-iron strips placed in water decomposes organic matter rapidly. It is recommended by eminent authority.

6. Charcoal is, possibly, the best substance for removing organisms chemically; but its efficiency is destroyed by an insoluble precipitate of either lime or iron. Messrs. Adkins & Co., of London, have patented a method to overcome this objection, by use of charcoal plates that may be easily scraped.

Filtration through spongy iron (by Rivers Pollution Commission—Parts in 100,000 parts):

	ORRGANIC CARBON.	ORGANIC NITROGEN.	PREVIOUS SEWAGE.
Thames water, before............	.120	.013	1340
Thames water, after.............	.025	.004	10

Filtration through animal charcoal:

	ORGANIC CARBON.	ORGANIC NITROGEN.	PREVIOUS SEWAGE.
Grand Junction Co.'s water, before..	.164	.030	320
Grand Junction Co.'s water, after...	.010	.002	950

SUBSIDENCE

is the most popular method of clarification of water by the deposition of heavy matter, accomplished in large storage reservoirs.

"If the reservoir be very small and shallow, and containing not more than a day's supply, for example, it is plain there can be but little opportunity for subsidence; but even in such cases, if the reservoir be kept full, or nearly full, the floating impurities might never enter the circulation. In the case of a large reservoir, holding many days' supply, it is quite different. Time is then afforded for the heavier impurities to settle to the bottom; and, if the water is admitted at one end and taken out at the other end of the reservoir, very little, if any, of the heavier particles can pass into the circulation; and we can see no reason why any of the superficial impurities, such as remain on or near the surface, should ever be allowed to enter the circulation."—(From Water Supply Commission of Engineers, Philadelphia, 1875.)

Fanning says:

"Subsidence does not completely clarify the water even in a fortnight or three weeks' time."

London has 262 acres of subsiding reservoirs for removing the turbidity of the Thames and Lea Rivers, and used as storage at times of sudden freshets.

Mere exposure to the air, even if accompanied by violent agitation, is comparatively powerless for the removal of polluting organic matter from water. Although, however, the flow of a river has thus but little effect in purifying the water by the oxidation of the dissolved organic matters, it has a most material influence in the removal by subsidence of a large proportion of the suspended impurities both organic and mineral, especially if the flow be sluggish in places.

In passing through still pools, the turbid streams let fall its

load of grosser mechanically suspended particles, and thus the water becomes clearer, although the dissolved impurity remains nearly as great as ever. It is, doubtless, this clarification by subsidence which has led to the very general but erroneous belief in the rapid self-purifying power of running water.

RESULTS OF SUBSIDENCE.

RIVERS.	SUBSIDENCE FROM 100,000 PARTS.		
	MINERAL MATTER.	ORGANIC MATTER.	TOTAL SOLIDS.
Irwell, after flow of 11 miles...	.88	.48	1.36
Irwell, after flow of 11 miles...	.38	.84	1.22
Mersey, after flow of 13 miles..	.10	.04	.14
Darwin, after flow of 13 miles..	.54	1.42	1.96

RESULTS OF SUBSIDENCE.

RIVERS.	PER CENT OF REDUCTION OF MATTER IN SUSPENSION.		
	MINERAL MATTER.	ORGANIC MATTER.	TOTAL SOLIDS.
Irwell, after flow of 11 miles..	47.8	50.	48 6
Irwell, after flow of 11 miles..	14.3	30.9	22.7
Mersey, after flow of 13 miles..	10.6	13.3	11.3
Darwin, after flow of 13 miles..	30.3	79.8	55.1

AERATION

is the destruction of animate life by oxidation, and is best accomplished by placing weirs across streams, sheet flashing, or spreading of water in thin sheets, or by roughness of beds or banks of running waters. The benefits may be ascertained, chemically, by the presence of nitrates and nitrites. The Water Supply Commission of Engineers, for the investigation of the water system of Philadelphia, say:

"This is one of nature's processes for purifying water, not only of the land, but of the ocean, and bodies of water deprived of it, other processes are apt to set in. It is, therefore, desirable that nothing should be done to obstruct this beneficial action. We have been informed that the cutting of ice, which was formerly allowed on the Fairmount pool, has been prohibited or discontinued. We would especially recommend that the cutting of ice on the pool be resumed, as an important sanitary measure, on account of the aeration it will

afford. If this were done systematically, it might remedy, at least to some extent, the disagreeable odor which we learn is sometimes noticed during the winter."

The aeration adopted by Mr. Moore, Supt. of Cincinnati Water Works, at Eden reservoir, improved the purity of the water twenty per cent., as shown by the analysis of Prof. Stuntz, who recommends the adoption of the process on a larger scale.

Covered Reservoirs, although used by the ancients, are now being recommended as highly beneficial to the purity of the water, by depriving the organic germs of their propagation elements of light and heat of the sun, preventing freezing of water, and reducing evaporation to a minimum. Paris has two such structures. Chelsea (London) Water-Works has one of ten million capacity that cost $110,000.00.

The temporary hardness of water is produced by absorption of carbonates, and may be reduced to softness by:

Distillation,	Boiling,
Carbonate of soda,	Caustic lime.

Permanent hardness is produced by sulphates, chlorides and nitrates of lime, and magnesia, and can not be dissipated by boiling.

An imperial gallon of pure water can take up but about two grains of carbonate of lime, but the presence of carbonic acid in the water will enable the same 70,000 grains (an imperial gallon) to take up twelve, sixteen, twenty, or more grains of the carbonate, and for each grain so taken up is one degree of hardness by the Clarke scale.

The system patented by Dr. Clarke, of England, in 1856, is the most practical method for the precipitation of lime, effected by means of a dilution of water with slaked lime, in the proportion of one of lime-water to ten of hard water. The system is in use in several small places in England, notably Canterbury, where 100,000 gallons are reduced, daily, at a cost of twenty-seven shillings per million gallons, with the following results:

	TOTAL SOLID IMPURITIES.	ORGANIC CARBON.	ORGANIC NITROGEN.	HARDNESS.
Before,	33.60	.012	.012	26.3
After,	11.94	.0	.0	4.9

Plumstead water-works, previous to its purchase by the Kent Water Company, of London, reduced, daily, 1,000,000 gallons by the Clarke method. The new owners, however, abandoned it.

From the testimony of a number of reputable physicians, before the Rivers Pollution Commission, of 1874, hard water, to a limited extent, ten degrees, was not considered injurious, and, by some, absolutely beneficial to health, although soft water, for a general water supply, was preferable.

Mr. Homersham, C. E., the designer of several of these works, testified, before this commission, that it cost £1, 7s. for precipitating 1,000,000 gallons. To introduce this system into London, with a consumption of 100,000,000 daily, the cost, he says, would be $3,000,000 for plant, and requiring over thirty-three acres of ground for basins, etc.

The relative sanitary condition of cities, in the United Kingdom, using hard and soft water, is shown in the following table:

NO. OF TOWNS.	AVERAGE POPULATION.	CHARACTER OF WATER.	AVERAGE RATE OF MORTALITY PER 10,000.
26	73,366	Not exceeding 5°	29.1
25	81,655	Above 5°, but not exceeding 10°	28.3
60	44,797	Above 10°	24.3
London	3,254,260	From 16° to 32°	24.6

The celebrated engineer, Mr. Bateman, of England, estimates the saving to Glasgow, by soft water, at $180,000 per annum; and if London used the same character of water, the equivalent would be $2,000,000 annually.

The use of lime, by private consumers, is recommended by the trustees of the water department of Columbus, O. They say that one ounce of lime, when added to thirty-six gallons of water, make it superior, for washing purposes, to the rain-water usually obtained from the cistern.

CHAPTER IV.

SYSTEM OF SUPPLY.

The systems of supply may be arranged under three general heads, viz:

1st. By springs and wells.
2d. By gravitation.
3d. By pumping.

SPRINGS AND WELLS.

We have, under this name, nature's resources for supplying our wants, whose facilities for furnishing the requisite supply depend upon the local rain-fall, configuration of the land, and the nature, or geological formation, of surface and subsoils.

Land springs are fed by rain-water, gravitating through loose permeable soils. The waters are very readily affected by infiltration of surrounding soils, and their course so easily changed in any direction that the permanence of such a source can not be relied upon.

Deep springs are fed by the waters falling upon and soaking down to great depths, and find their way to the surface through some fault, upheaval or other great geological disturbance, or between some impermeable strata The most copious springs are in the tertiary strata, and the law, as regards their abundance, is "the rarer the visible springs may be, the more copious they would be found." The permanence of the springs can only be relied upon after careful gauging, extending over several years.

Wells may be separated under the following divisions:

Shallow, or dug wells.
Ordinary deep, or pump wells.
Artesian wells.

"Shallow and deep wells are those which are sunk throug' permeable stratum, and form, as it were, reservoirs, into whi h land springs may filter and accumulate; whilst artesian wells ar

which are sunk through an impervious upper stratum, to reach a subterranean water-bearing stratum lying, in its turn, upon an impervious upholding bed. In the former cases, the quantity of water obtainable is simply that which can filter through the sides of the well to replace the water removed, or which may accumulate in any reservoir formed below; whilst, in the latter case, the quantity obtainable will depend simply upon the power of the water-bearing stratum to transmit water.

"In the case of deep-seated wells, the probable yield of water must depend, primarily, upon the area of permeable strata likely to affect the supply, and upon the facilities those strata may offer for the passage of water; and, secondly, upon the rate of consumption which takes place in the neighborhood, for the quantity of water which any particular stratum can supply is only a limited quantity; so that, evidently, if the water be taken at one point, no more will remain for the other."—(Hydraulic Engineering, Weale's Series.)

The above fact is illustrated, practically, in London, where the water line of the chalk formation has been permanently lowered to the extent of fifty or sixty feet below Trinity high-water mark; and it is even stated that the level of the water in the wells, near the summit of this formation, rises, on the Monday morning, in consequence of the cessation of pumping in London during the Sundays. The experience of Liverpool corroborates this fact: that the Windsor well, having a depth of 210 feet, affected the surrounding wells to a maximum distance of a mile and three quarters. The celebrated engineer and originator of the well system of Liverpool, Robert Stephenson, from long experience and careful observation, offered the following conclusions (from Hughes water-works):

"That an abundance of water is stored up in the new red sandstone, and may be obtained, by sinking shafts and driving tunnels, about the level of low water.

"That the sandstone is generally very pervious, admitting of deep wells drawing their supply from distances exceeding one mile.

"That the permeability of the sandstone is occasionally interfered with by faults or fissures filled with argillaceous matter, sometimes rendering them partially, or wholly, water tight.

"That neither by sinking, tunneling, nor boring, can the yield of any well be very materially and permanently increased, except so far as the contributing area may be thereby enlarged.

"That the contributing area to any given well is limited by the amount of friction experienced by the movement of the water through the fissures and pores of the sandstone; and

"That there is little or no probability of obtaining, permanently, more than about 1,000,000 or 1,200,000 gallons a day from each well, and this only when not interfered with by other deep wells."

Statistics of the flow of the Windsor well show that the yield, in 1843, was 1,152,000 gallons per day; in May, 1848, 807,061 gallons; in January, 1850, from 705,667 to 634,752 gallons. The observations of the Green Lane well, in the same city, give the decrease in flow, per annum, at 4.7 to 6 per cent.

A plan has been proposed, by Mr. Bailey Denton, that, in order to increase the water-bearing stratum under London, sufficiently for a water supply, and also secure the well-known benefits of the filtration powers of the chalk, to let the Thames water pass down to the chalk, through the London clay, by means of wells sunk or bored. The objections raised against this plan is the possibility of the wells becoming choked by accumulation of impurities.

Mr. J. T. Fanning in his valuable "Treatise on Water Supply Engineering," says:

"The success of wells, penetrating deep into large subterranean basins, upon the first completion, has usually led to their duplication at other points within the same basin, and the flow of the first has often been materially checked upon the commencement of flow in the second, and both again upon the commencement of flow in a third, though neither was within one mile of either of the others. The flow of the famous well at Grenelle was seriously checked by the opening of another well at more than three thousand yards, or nearly two miles distant."

POLLUTION OF WELL WATER.

It is stated that about fifteen millions of the British population live in towns and urban districts. Even if we assume,

which is not yet the case, that all these people are supplied by water-works, the remaining twelve millions of county population derive their water almost exclusively from shallow wells, and these are, so far as our experience extends, almost always horribly polluted by sewage and by animal matter of the most disgusting origin,

As the contents of the water-hole or well are pumped out, they are immediately replenished from the surrounding disgusting mixture, and it is not therefore very surprising to be assured that such wells do not become dry even in summer. Unfortunately, excrementitious liquids, especially after they have soaked through a few feet of porous soil, do not impair the palatability of water; and this polluted liquid is consumed from year to year without a suspicion of its character.

Our acquaintance with a very large portion of this class of potable waters, has been in consequence of the occurrence of severe outbreaks of typhoid fever amongst consumers of this character of water.

"The samples of water from deep unpolluted wells were obtained from wells or bore-holes of a depth rarely less than 100 feet, and reaching in one case 1,285 feet. In many cases these wells were partly or wholly supplied by surface-polluted water. Such water, when it penetrates only to shallow wells still retains a considerable proportion of its polluting organic matter in an unoxidized condition: but when it descends through one hundred feet or upwards of porous soil or rock, the exhausted filtration to which it has been subjected in passing downwards through so great a thickness of material, and the rapid oxidation of the dissolved organic matters in a porous and aerated medium, afford a considerable guarantee that all noxious constituents have been removed."—(Rivers Pollution Commission, 1874.)

"Deep wells may become polluted, either by admission of soakage from the superficial strata into the shaft of the well, or by access of polluted water through open fissures in the rock in which the well is sunk."—(Rivers Pollution Commission, 1874.)

"Even where wells are sunk to great distance (one was sunk at Bondy, near Paris, to a depth of 247 feet), the surrounding soil is not free from danger of pollution by the soaking of the foul liquid into

the side of the well."—(Fifth report Massachusetts State Board of Health.)

The following table shows the average analysis of ten worst examples of well water (parts in 100,000 parts):

	AV. DEPTH.	CARBON ORGANIC.	NITROGEN ORGANIC.	CHLORINE.	HARDNESS.
Shallow wells,	...	1.560	.241	16.56	63.24
Deep wells polluted,	...	.363	.092	9.45	36.27
Deep wells unpolluted,	380	.151	.032	14.14	27.4

ARTESIAN WELLS.

Artesian is the name applied to water-springs rising above the surface of the ground by natural hydrostatic pressure, or boring a small hole down through a series of strata to a water-bearing bed inclosed between two layers. It was first practiced in 1100, in province of Artois, France, whence it derives its name.

"The second and tertiary geological formations, such as those underneath London and Paris, often present the appearance of immense basins; the boundary or rim of the basin having been formed by an upheaval of the subjacent strata. In these formations it often happens that a porous stratum, consisting of sand, sandstone, chalk, and other calcareous matter, is included between two impermeable layers of clay, so as to form a flat, porous 'U' tube, continuous from side to side of the valley, the outcrop on the surrounding hills forming the mouth of the tube. The rain filtering down the porous layer to the bottom of the basin, forms there a subterranean pore, which, with the liquid or semi-liquid column pressing upon it, constitutes a sort of huge natural hydrostatic bellows; sometimes the pressure on the superincumbent crust is so great as to cause an upheaval or disturbance of the valley, and there can be little doubt that many earthquakes that are manifestly not of volcanic origin, are due to this simple cause." —(Ninth edition Encyclopedia Britannica.)

"An overflow results only when the surface that supplies the water-bearing stratum is at an elevation superior to the surface of the ground where the well is located, and the water-bearing stratum is confined between imperrious strata. In such cases the hydrostatic pressure

from the higher source forces the water up to the mouth of the bore."
—(Fanning Water Supply.)

"In the tertiary formations the porous layers are not so thick as in the secondary, and, consequently, the occurrence of underground lakes is not on so grand a scale; but there being more frequent attenuation of these sandy beds, we find a greater number of them, and often a series of natural fountains may be obtained in the same valley preceding from water-bearing strata at different depths, and rising to different heights.

"It does not follow that all the essentials for an Artesian well are present, though two impermeable strata, with a porous one between, may crop out around a basin. There must be, in the first place, continuity of the permeable bed for the uninterrupted passage of the water, and there must be, on the other hand, no flaw or breach in either of the confining layers by which the water might escape. To one or the other of the causes is due the failure of many attempts to find Artesian wells, where, from appearances, they might be expected. It has occasionally happened that on deepening the bore, with the hope of increasing the flow of water, it has ceased altogether, doubtless from the lower confining layer being pierced, and the water allowed to escape by another outlet.

"The subterranean bore is frequently of small extent, and of the nature of a channel rather than of a broad sheet of water; and the existence of one spring is no guarantee that another will be found by merely boring to the same depth in the neighborhood.

"The preliminary theoretical determination of the existence of these Artesian conditions is in itself a difficult matter, and can be arrived at only by a thorough acquaintance with the geological disposition of the district."—(Ninth edition Encyclopedia Britannica.)

"The question of a supply of water from deep wells, made by boring, and commonly called artesian, has been somewhat discussed in Philadelphia, but there is no probability that an adequate supply, for the general use of the city could be obtained in that manner; and the quality of the water obtained from such wells varies very much in different localities, depending upon the nature of the strata from which the water is procured, and this Commission can not recommend any dependence upon such plans for the general city supply, attended, as they are, with great expense and extreme uncertainty, and being, in

every case, more or less experimental."—(Philadelphia Water Supply Commission of Engineers, 1875.)

The flowing water of the Kissingen spring, Bavaria, is produced by carbonic acid gas.

TEMPERATURE OF WELLS.

Invariably the temperature of water from great depths is higher than at the surface, this being due to some unknown source of heat in the interior of the globe.

In Scotland, the rate of increase of temperature, after permanent degree has been attained, is about one degree Fahrenheit for every forty-eight feet of descent.

At Grenelle, the temperature was found to be 1.8 degrees for every 106 feet of descent below the point of constant temperature.

The average rate of increase of temperature is one degree for a descent of from forty to fifty feet.

The temperature of the boring at Columbus increased, below the permanent line, one degree in every seventy-one feet.

EXAMPLES OF ARTESIAN WELLS.

The famous well at Grenelle, France, was commenced, by the government, in 1834, and after repeated failures and discouragements almost to abandonment, notwithstanding the urgent representations of the scientist Arago, that water would be found, the end was accomplished at the depth of 1,798 feet, in the year 1843. The diameter of the bore is 3½ inches; capacity, 600 gallons per minute; temperature of water, 82 degrees; height of flow, 128 feet. The expense attending this boring was 300,000 francs. The Passy well, near Paris, supplied from the same water-bearing stratum of the Grenelle, is 1,923 feet deep; 2′ 4″ inches bore at bottom; capacity, 5,582,000 gallons per day; height of flow, 54 feet. The La Chapelle well was started in 1866, with a gigantic bore of five feet seven inches, and by November, 1869, had reached a depth of 1,811

feet, the intention of the engineer being to exend it to a depth of 2,950 feet.

At the part of Paris named Butte-aux-Caelles, a well was started, in 1866, of six and a half feet diameter, to be carried down to a depth of 2,600 to 2,900 feet.

The Kent Water-Works, of London, is supplied by wells in the chalk formation, yielding 9,000,000 gallons daily. This great flow is due to what is known as a fault in the London basin strata.

St. Louis has a well 3,147 feet deep.

Louisville has a three-inch well, 2,086 feet deep, with a capacity same as the Grenelle well.

There have been nine artesian wells successfully bored in Cincinnati, a description of which will be found on page 107.

Charleston, South Carolina, has an artesian well 1,970 feet deep, from which pure soft water, of 90° temperature, flows ninety feet above the surface. It has five inch tubing on top and two and three-fourths inch diameter at bottom. The cost was $2.500.00, and the time required in sinking was a little more than a year. There is also an artesian well, in the same city, 1,250 feet deep, which discharges 25,000 gallons a day, of water, at a temperature of eighty-eight degrees, strongly impregnated with sodium and magnesium.

The desert of Sahara has a number of well borings, some yielding as high as 1,500,000 gallons daily. The depth varies from 130 to 400 feet, and temperature 70 to 77 degrees.

The Ohio State authorities undertook to supply the capital by an artesian well. After two failures, in attempting to tube out the quicksand, they succeeded (in November, 1857) in piercing through the rock, and at a depth of 149 feet a vein of water was struck that continued to wash away the borings for nearly 100 feet below. On the 1st of October, 1870, a depth of 2,775 feet was reached, but no flowing water obtained, when the undertaking was abandoned for want of an appropriation.

The record of the boring is tabulated as follows:

	SYSTEM.	GROUP.	STRATA.	THICKNESS.
				FEET.
1	Drift.	Alluvial drift.	Clay, sand, and gravel.	123
2	Divonian.	Base of Hamilton. Helderberg.	Dark bituminous shale. Dark and gray limestone with bands of chert.	15
3	Upper Silurian.	Niagara.	Sandy above, darker and argellaceous below.	626
4		Clinton.	Red, brown, and gray shales and marls.	162
5	Lower Silurian.	Hudson Trenton.	Greenish calcareous shale.	1058
6		Calciferous.	Light drab sandy magnesian limestones.	475
7		Potsdam.	White sand-rock, calcareous.	316

Temperature of well at bottom, 88 degrees, being uniform for 90 feet, at 53 degrees, will make an increase of one degree for every additional 71 feet. It was the opinion of Prof. Newberry, that, if water was successfully struck, it would be of a saline character.

Dubuque, Iowa, is supplied by a spring accidentally struck while tunneling in a neighboring drift.

At the upper basin of the Thames River there are seven springs, whose capacity is estimated at 32,000,000 gallons daily.

Liverpool, England, has four wells, with a combined capacity of 6,000,000 gallons daily.

Birmingham, England, has four wells, from which the water company derives 8,000,000 gallons daily.

Washington has over 400 wells, and Cincinnati about 300, nine of which are artesian, that were bored by private enterprise.

The deepest well in the world is near Berlin—4194 feet deep without piercing the salt formation.

WELL BORING.

The art of boring into the earth was practiced by the Chinese 2,000 years ago, the feature of their system being the percussive action of a tool suspended by a flex'ble rope.

The system now practiced in Great Britain, and on the Continent, is that in which the tools are attached to rods, consisting of a number of lengths, from ten to thirty feet long, joined by a separate collar, with a combined vertical and definite rotary motion, produced by a swivel joint in the upper length, or by suspending the rod to a "dog." An ordinary well is first sunk to such a depth that the water below will rise, through the boring, into it. The object is to partly facilitate the object of boring, but chiefly to enable the pumps to be fixed without too great a length of suction. In deep wells, windlasses, driven by steam power, are used for operating the tool; the size of rod being, usually, 1¼ inch square; but for an eight foot boring, a 4½ inch square rod was used. To reduce the jaring and vibration, where borings are of considerable depth, the rods are hollow, in order to give same rigidity and resistance to torsion with less weight, and made buoyant, when working in water, by filling the rod with cork or light wood. A sliding joint, known as the "Oëuyenhausen joint," is frequently used to bring the jarring only on that portion of the boring rod below. A shell pump is employed, in combination with the boring tool, for gathering the detritus, which obviates frequent raising of rod. Free-falling tools, guided by sliding joint, with catch or pall to raise same, are largely used. The weight of tool depends upon the depth and character of boring, that of the La Chapelle well being four tons.

In the oil-well boring of Pennsylvania, the rope (with about 50 feet of iron bar, sliding jaws, sinking bar, flat drill and sand pump attached) are exclusively preferred.

PRACTICAL EXAMPLES OF WELLS AS SOURCES OF SUPPLY ONLY.

Where the surface soil and underlying drift possess sufficient porous qualities for absorption of a large portion of the rain-fall, together with the natural benefits of the impervious stratum beneath, having a proper axis of inclination favorable for conducting the infiltration of adjoining water-sheds, a large supply of water may be secured by the construction of dug wells for intercepting the subterraneous water.

Fanning has computed the following available quantities, under favorable circumstances, for percolation, from one square mile of porous gathering area (the mean annual rain being assumed at forty inches depth).

MONTH.	RATIO OF 1-12 OF MEAN ANNUAL RAIN. INCHES.	VOLUME OF PERCOLATION IN DRY YEARS. CUBIC FEET.	NO. OF PERSONS IT WOULD SUPPLY AT FIVE CUBIC FEET DAILY.
January,	.737	1,712,198	11,264
February,	.796	1,479,878	9,736
March,	1.070	2,237,242	14,719
April,	.814	566,861	3,729
May,	1.462	387,974	2,552
June,	.964	88,282	581
July,	1.077	51,110	336
August,	1.251	30,202	199
September,	1 015	46,464	305
October,,	1.076	989,976	6,572
November,	.937	2,176,838	14,321
December,	.801	2,604,307	17,133

The city of Brooklyn gathers its supply by intercepting ponds. The source is the southern slope of Long Island, with a drainage area of 60.25 square miles. The plain is composed of fine sand, which is saturated with excellent water, the surface of which rises twelve feet per mile from the tide level at the shore, and which appears at the surface of the ground in springs and streams, where depressions occur in the ground level. The minimum observed flow occurred in 1880, and was equal to 9.4 inches on the water-shed. The available supply is, at times, quite small.

The city of Lynn uses a driven well partly, of which they say, in their annual report for 1880:

"The doubtful character of any underground supply of water, especially when it is drawn from beneath a territory occupied by a densely settled community, makes frequent examination of its quality a duty not to be disregarded. We invite attention, however, to the fact that the chemical examination of the well water has shown an increasing quantity of foreign matter mingling with it as pumping proceeded, and that this increase suggests an inflow of water

to the wells from some other source than that from which it was at first drawn."

This method of securing water, however, is largely resorted to in the origin of water-works for small cities.

The Sanitary Engineer (Vol. v, No. 5) refers to a proposed well for Lincoln, Nebraska, a town of 15,000 inhabitants, that the contractor proposed to dig for the sum of $10,000. The estimated capacity will be ten million gallons a day, and the editor of the paper observes:

"If a large well is sunk in a very saturated and porous soil, it will probably furnish the amount required for the city (one million gallons) at first, possibly a great deal more. But in five years' time it is not hazardous to predict that such a well will not yield enough water for Lincoln. As for furnishing ten million gallons a day for any length of time, there is no well in the world, which we know of, of such a capacity, and all experience is against the probability of such an one being discovered."

GRAVITATION

is that system of supply where the rain-water drainage of elevated water-sheds is gathered in natural or artificial storage basins, and conveyed through conduits by gravitation to the point of supply. The important points entering into the consideration of this method are:

1. Character of water; present and future contamination.
2. Water-shed; present and future requirements for quantity and availability, with proper knowledge of the geology of the surrounding country.
3. Rain-fall, absorption and evaporation.
4. Elevation and distance of source.
5. Route of conduit.
6. Cost of construction.

The practical objections to the system are:

1. Contamination of source by surface drainage of cultivated lands; pollution of feeding streams, or growth of vegetation.
2. Necessity for large impounding reservoirs for storage of water

during rainy seasons, requiring immense puddled walls, whose stability is questioned.

3. The uncertainty of dependence on the requisite rain-fall, and liability of short supply, or a possibility of water-famine.

4. The large expenditure at the outstart for construction of supply that must be ample for future demands.

Surface waters from calcareous cultivated lands are polluted with but a moderate amount of organic matter; but, as some of this matter is almost always of animal origin, they are always undesirable, and may at any time become dangerous for domestic use.

If necessity compels their use, great care ought to be taken to secure their efficient filtration before they are delivered to consumers. This affords some, though by no means complete, protection from the propagation of zymotic disease through the agency of such waters.

They are generally very hard, and, unless artificially softened, occasion a great waste of soap when used for washing. Of all the waters of this description, those which flow from the surface, or from the drains of sewage farms, are generally most impure, because the time during which the foul sewage is exposed to the purifying action of plant and soil is reduced to a minimum.

Surface water from non-calcareous soil is generally soft but usually turbid and subject to animal contamination. Such water should always be carefully filtered.

ANALYSIS OF LAND DRAINAGE WATER FROM SEWAGE FARMS (PARTS BY WEIGHT OF 100,000 PARTS).

	TOTAL IMPURITIES.	ORGANIC CARBON.	ORGANIC NITROGEN.	CHLORINE.	PREVIOUS SEWAGE OR ANIMAL CONTAMINATION.	HARDNESS.
Worst Condition.	94.	2.160	.274	13.10	10.090	35.58
Best "	24.60	.108	.055	4.05	17.920	9.20
Average "	64.02	.982	.191	6.36	10.443	33.09

Much depends upon the knowledge of the climatic influences and rain-fall, extended, as it should be, through years of obser-

vation in determining the available quantity of water. Engineers, however, are liable to be too sanguine of the resources from water-sheds, by assuming, as a general rule, the average, rather than the minimum, rain-fall.

In 1868 nearly all the cities and towns of England, supplied by gravitation, suffered a water-famine, because of the over-estimate of the available rain-fall, and in an insufficient provision of storage for an unusually long drought. Although the rain-fall for the year was above the average, yet it was unequally distributed.

The authorities of Manchester were obliged to publish official notices cautioning the inhabitants against waste, and, on the 3d of August, limited the supply to the city to twelve hours of the day, stopped the street watering, and diminished the trade supplies by one-half. In the middle of September the general supply of the town was further limited to eight hours per day. Many persons were prosecuted for waste or undue use of water.

Liverpool, Sheffield, Bristol, and several other large cities were obliged to resort to like severe methods enforced at Manchester. New York has been using every gallon that the aqueduct is capable of supplying; and, during the drought of last summer, when the head of water at Croton Lake was diminished, the capacity of the aqueduct was so reduced that the flow of water to the city was reduced, and a water-famine averted only by a Providential rain-fall.

The rule observed among engineers, in Great Britain, in determining the calculated rain-fall, is the deduction of one-sixth from the average rain-fall of twenty years for an average annual rain-fall of the three driest consecutive years in that period. But, as Mr. Homersham, C. E., observes, the axiom in mechanics, that the strength of a beam is the strength only of its weakest parts, applies also to gravitation water-works, their real strength or power of supply being only the minimum quantity they may be reduced to.

Allowance for absorption depends upon the geological formation and stratification, and for evaporation, upon local influences.

The following is taken from Hughes' Water-Works:

"A flat, low-lying country is seldom well adapted for the impounding of water by embanking across the valleys. In such a district, long and shallow embankments would be required, and these would cause the water to spread out over a great area with a very shallow depth. Under these circumstances, the water is apt to vegetate and become highly impure. Again, in low-lying districts of flat countries the rain-fall is seldom nearly so great as in upland districts, so that much larger drainage areas must be sought."

In addition to the general configuration of the valleys, which ought to be deep and with precipitous sides, flanked by lofty hills, there are several other points which require attentive examination in projects for collecting water from drainage areas:

1. The area of water-shed.

2. The geological character of the soil as affecting its capacity to absorb rain, and to allow the infiltration of water through it.

3. The character of the surface soil as affording soluble ingredients which may be taken up by the water and serve to contaminate its quality. In this point of view, districts of decomposing peat, districts of arable agricultural land richly manured, and places thickly covered with population, are often highly objectionable.

4. The rain-fall of the district, and especially the minimum fall in any one year.

5. The nature of the surface-soil as affording facilities for procuring puddle and constructing retentive reservoirs.

6. The consideration of compensation to mill-owners and possibly to land-owners where the water is used for irrigation.

The geological structure is extremely important in estimating the capacity of a drainage area. It is not alone the rain which falls on the sloping surface of the hills, and finds its way by gravitation to the lower levels; but the effect of springs is also very great in augmenting the quantity of water. Many drainage areas are also valleys of elevation, in which the strata dip in opposite or anticlinal directions on opposite sides of the valley. In this case it is evident that much of the rain falling on a porous surface will insinuate itself between the partings of the strata, and flow off in a direction contrary to that of the surface drainage.

From Mr. Beardmore's work we take the following, as the proportion or percentage of rain-fall which flows off the surface:

"From twenty examples we have 89 as the largest per centage, the lowest 29 per cent., and the average 64 per cent.

"The Eaton Brook water-shed, in Madison County, New York, of 6,800 acres, with steep slope and compact soil, underlaid by hard greywacke rock, elevated 1,350 feet above the sea, availed 66 per cent. of the rain-fall as surface flow.

"A similar water-shed, Madison Brook, gave 50 per cent. Experiments by Wm. McAlpine, for Albany water-works, shows that from a water-shed of 2,600 acres, 41½ per cent. of the rain-fall was carried off by the streams from May till October, inclusive, while from November till April, 77.6 per cent. was so carried off."

In England the allowance for absorption and evaporation ranges from nine to nineteen inches per annum. In this country it is from 75 to 100 per cent. greater.

We produce from "Fanning's Water Supply" the following table of experiments on evaporation from surfaces of shallow tanks:

Cambridge—	Length of trial,	one	year;	evaporation	in inches,	56.00
Salem	"	"		"	"	56.00
Syracuse	"	"		"	"	50.20
Ogdensburgh	"	"		"	"	49.37
Dorset, England	"	three	years	"	"	25.92
Oxford "	"	five	"	"	"	31.04
Bombay	"	five	"	"	"	82.28
Croton	average,	six	"	mean evap. equal 81 per cent. of rain-fall.		39.21
Lea Bridge, London	"	seven	"	average rain-fall		27.7
				annual evap. min.		12.067
				" " max.		25.141

The following from the same author of the minimum flow of streams in cubic feet per second, per each square mile of water-shed:

From	1 square mile	.083	From	250 square miles	.25
From	10 square miles	.1	From	500 square miles	.40
From	25 square miles	.11	From	1,000 square miles	.35
From	50 square miles	.14	From	1,500 square miles	.38
From	100 square miles	.18	From	2,000 square miles	.41

From the different surfaces, its ratio of the annual rain, including floods and flow of springs, is approximately as follows:

	PER CENT.
From mountain slopes or steep rocky hills,	80 to 90
From wooded swamp lands,	60 to 80
From undulating pasture and woodland,	50 to 70
From flat cultivated land and prairie,	45 to 60

MONTHLY EVAPORATION FROM RESERVOIR.

(*From Fanning.*)

	JAN.	FEB.	MAR.	APR.	MAY.	JUNE.	JULY.	AUG.	SEPT.	OCT.	NOV.	DEC.
Mean ratio—inches	.30	.35	.50	.80	1.45	1.70	1.85	2.00	1.45	.75	.50	.35

AVERAGE AVAILABLE RAIN-FALL FOR STORAGE PURPOSES.

(*From Fanning.*)

	JAN.	FEB.	MAR.	APRIL.	MAY.	JUNE.	JULY.	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL.
Gain by rain—inches	2.00	2.21	2.40	2.93	3.47	2.88	2.99	3.00	2.67	2.53	2.48	2.24	32.
Loss by evaporation—in.	.60	.70	1.00	1.60	2.90	3.40	3.70	4.00	2.90	1.50	1.00	.70	24.
Difference—Gain inches	1.40	1.51	1.40	1.33	.57	......	.....	......	......	1.03	1.48	1.54	8.
Difference—Loss inches	......	......	......	.....	......	.52	.71	.80	23	......	......	......	......

SUMMARY OF FLOW OF RAIN-FALL IN CU. FT. PER MINUTE PER SQUARE MILE.—(*From Fanning.*)

	AT LAKE COCHITUATE CU. FEET.	AT CROTON BASIN CU FEET.		AT LAKE COCHITUATE CU. FEET	AT CROTON BASIN CU. FEET
January,	99.17	92.48	July,	45.27	48.37
February,	150.42	147.69	August,	49.15	70.22
March,	174.76	177.02	September,	42.84	85.99
April,	169.80	132.63	October,	62.45	81.08
May,	131.80	164.49	November,	75.90	124.92
June,	44.27	115.12	December,	78.94	106.23

AQUEDUCTS.

The plan, as adopted by Mr. Hawskley at Liverpool, and Mr. Bateman at Glasgow, of subterranean pipes, is now universally followed by engineers. And there is no longer any excuse for incurring the outlay which must attend the erection of monumental structures, such as were necessary in the times of the ancient Romans.

The engineer of Marseilles Conduit adopted the "Pont du Gard" plan for conducting the waters of the Durance, in preference to iron pipes, and constructed the splendid folly, "as Humber terms it," of the aqueduct "Roquefavour." The dimensions are:

Length, 1,289 feet.
Height, 266 feet.
1st tier of 12 arches each 49½ feet span.
2d tier of 15 arches each 52½ feet span.
Upper tier of 54 arches each 16½ feet span.

The cost was $750,000, while inverted syphon pipes could have been laid for one-third of this sum.

The aqueduct for Glasgow is thirteen miles in tunnels, 3¾ miles of iron-piping across valleys, and nine miles of opening cutting and bridges. There are eighty distinct tunnels, and twenty-five important iron and masonry aqueducts. On the line is the Drymen bridge on masonry piers, eighteen feet apart, with two pipes surrounded by wood lagging, a forty-eight-inch syphon at Aberfoyle Road, and a lofty bridge at Ballewan, seventy feet in height.

The Aberdeen water-works has a thirty-six-inch syphon, 1,200 feet in length, across Cullen Burn, supported by granite piers.

The Croton aqueduct is a masonry channel lined with brick. The bottom is an inverted arch with cord 6.75 feet, and versed sine 0.75 feet; side walls are 4 feet high, and battered so that at the top they are 7′ 4″ apart, and surmounted with a semi-

circular arch. The interior is 8.64 feet high, and area 53.34 square feet.

The grade is 0.021 feet per 100 feet, total length 38 miles. It crosses the Manhattan Valley 2 miles in extent, with two 36-inch, one 48, and one 60-inch cast-iron pipes, and over the Harlem River by granite bridge, known as High bridge, 100 feet above high water, composed of seven 50-feet and eight 80-feet spans. The conduit over the bridge consists of two 36-inch cast-iron pipes, and a wrought pipe 7 feet 6½ inches in diameter, resting upon saddles, supported by cast-iron standards placed 12 feet apart between the 36-inch pipes.

The aqueduct over Cabin John Creek, of Washington, D. C., water supply, consists of a single arch of masonry 220 feet span, is the largest masonry arch in the world. The rise is 57 feet 7 inches, thickness of crown 4 feet 2 inches, and at spring 6 feet 2 inches. Water is conveyed in an iron pipe 9 feet in diameter, built in solid masonry.

The bridge over Georgetown Creek, on line of Washington Conduit, is 200 feet span with two cords of iron pipe 4 feet in diameter, 1½ inches thickness, used as water conductors. The pipes were first lined with staves of resinous pine 3 inches thick to prevent freezing, but have been taken out. No allowance is made for expansion or contraction. A similar plan is in use at Philadelphia, over the valley of Wissahikon, consisting of two 20 inch cast-iron flange pipes serving as top members of a series of inverted bow-string trusses. There are four spans, each 169 feet 9 inches. Center span 100 feet above ordinary level of the water.

The Boston aqueduct crosses the Charles River by syphon pipes—two, 30 inches, and the other 36 inches in diameter. Starting from a pipe chamber on the western side of the valley, the pipe descends 52.11 feet below the level of conduit, and rests on a masonry bridge of three arches.

One of the syphons for supplying Madrid, Spain, crosses a valley 4,560 feet in length, consisting of four lines of cast-iron pipes three feet in diameter.

Dublin is supplied through 30,336 yards of 33-inch and 8,272

yards of two lines of 27-inch cast-iron pipes—20,000 yards laid through private property. The average fall is 20 feet per mile. There are three relief-tanks on line of 33-inch pipe. The capacity of this pipe was calculated at sixteen millions per day, while the actual delivery exceeded twenty millions.

Toronto is supplied by a 4-foot wooden pipe, 7,000 feet in length, under pressure.

Manchester, N. H., has a wooden penstock, six feet in diameter, 600 feet in length, that conveys supply to water wheels, under a head of twelve feet at entrance and thirty-eight feet at outlet.

The new conduit for water supply of Baltimore is a continuous tunnel, seven miles long, running from the dam to the receiving reservoir—"Lake Montebello." In its construction no open cuts were made; all work being done by drifting. Its depth below the surface of ground varies from 65 to 360 feet. The internal diameter is 12 feet; the fall is one foot per mile; capacity 170 millions daily. Fifteen shafts were sunk during the constructive work. Two miles of the tunnel were through material that required to be arched with brick; the remaining distance was through very hard rock that did not require arching. The cost of this structure was about two millions of dollars.

Chicago has two tunnels under Lake Michigan, parallel with each other, 46 feet apart, extending to a crib, located in the lake, two miles from the shore. The first one was started, in 1864, under adverse criticism, and successfully completed in 1867. The cost, with the crib, was $457,800. It is five feet horizontal diameter, and 5′ 2″ vertical diameter, and made of brick. The second one was built in 1872-'74; is five feet in diameter, lined with brick. It extends from the North Side Works, a further distance of 20,000 feet, under the city and Chicago River to West Side Works. The cost of this tunnel, under the river, was $414,000, and under the city $543,000. The nature of the excavation was generally through stiff blue clay with occasionally pockets of quick sand.

The Sudbury conduit, of Boston Water-Works, is sixteen

miles long, with a grade of 1.056 feet per mile. The top is a semicircle of nine feet diameter, and the bottom is an arc of 13.22 feet radius, struck from a center 5.53 feet above the crown of the arch. The sectional area is 56.75 square feet. The foundation is of concrete; the side walls and spandrel backing of rubble stone masonry; the lining of brick, four inches thick, and the arch of brick, twelve inches thick. The Charles River is crossed by a granite bridge, 475 feet long and 75 feet high, with two segmental and five semicircle arches.

On the line of the Vanne conduit there is an aqueduct made entirely of "beton," which spans the valleys and quicksands in the great forest of Fontainebleau, between La Vanne River and Paris.

CONDUIT DATA.—(*From Fanning.*)

LOCALITY.	WIDTH IN FEET.	HEIGHT IN FEET.	DEPTH OF WATER IN FEET.	HYDRAULIC MEAN RADIUS.	SINE OF INCLINATION OF WATER SURFACE.	VELOCITY PER SECOND IN FEET.	COEFFICIENT M.	DAILY DELIVERY AT GIVEN DEPTH, U. S. GALLONS.	TOTAL DAILY CAPACITY, U. S. GALLONS.
Cochituate, Boston	5.	6.333	6.333	1.417	.0000496	1.	.00452	16,398,000	16,500,000
Croton, New York	7.47	8.458	6.083	2.341	.00021	2.218	.00643	59,340,000	100,000,000
Washington	9.	9.	3.465	1.873	.00015	1.893	.00505	27,560,000	100,000,000
Brooklyn	10.	8.667	5.	2.524	.0001				70,000,000
Sudbury, Boston	9.	7.667	5.3		.0002				70,000,000
Baltimore	9.	9.							170,000,000
Loch Katrine, Glasgow	8.	8.	6.85	2.525	.0001587	1.7126	.00876	60,000,000	60,000,000
Canal of Isabel III, Mad.	7.052	9.184							52,000,000
Vanne, Paris	6.6	6.6	5.		.0001				23,500,000
Dhues, "	2.3	3.5			.0001				5,500,000
Pont du Gard, Nismes	4.		3.333		.0004	2.			14,000,000
Pont Pyla, Lyons	1.833		1.833		.00166	2.95			
Metz	3.167		2.167		.001	2.738			

DAMS.

The disastrous failures of earth dams has excited suspicion as to the stability of such structures; but when we consider the immensity of the dams in India, our concern should be only for the care and attention given to their construction. There the material used is well puddled; then a drove of cattle is turned loose on the fill, to stamp the earth thoroughly. This

method is repeated in layers until the required height is reached. Often the Sepoys do the stamping.

The Veranun reservoir dam is twelve miles in length; and the amount of earth, of which it is composed, will encircle the globe with a belt six feet in thickness.

There is a dam on the island of Ceylon made of huge stone blocks strongly cemented together and covered over with turf, making a solid barrier of fifteen miles in length, one hundred feet wide at the base, sloping at top to forty feet, and extending across the lower end of a spacious valley.

DIMENSIONS OF RESERVOIR DAMS.—(*From C. H. Beloe.*)

NAME OF WORKS.	NAME OF RESERVOIR.	MAXIMUM DEPTH OF RESERVOIR.	RATIO OF SLOPES.		PUDDLE WALLS.				WIDTH OF TOP BANK.	WIDTH OF BYE WASH.
			INNER.	OUTER.	MAX. DEPTH.	THICKNESS AT SURFACE.	THICKNESS AT TOP.	BATTER.		
					′	′ ″	′		′ ″	′
Bolton Water-Works.....	Heaton.	35	3 to 1	2 to 1	6	8 3	4	1 in 15	13 6	12
" " "	Wayoh.	76	"	2½ to 1	70	20 6	8	1 in 12	22	105
Liverpool	Roddlesworth.	64	"	2 to 1	120		6	1 in 12	16	60
"	"	78	"	"			6	1 in 12	18	
"	Anglezark.	35	"	"	50				30	
Bradford......................	Stuben.	55	"	"	40	12	6	1 in 18	12	15
"	Chelker.	36	"	"	30	12	6	1 in 12	12	
"	Barden.	68	"	"	64	15	6	1 in 15	12	24
"	Doe Park.	52	"	"	78	12	6	1 in 18	12	15
"	Silsden.	78	"	"	40	12	6	1 in 24	12	15
"	Gwmwith.	66	"	"	50	14	6	1 in 18	12	40
Rhyl District..............	Llanefwydd.	52	"	"	119	9	3	1 in 18	10	12
Warrington W. W		13	1½ to 1	"					3	

One of the recent dams of the Croton supply, made of concrete, is thirty-one feet at the base, eight and one-half feet at top, six hundred and seventy feet long, and seventy-eight feet high. The main embankment, which forms Lough Vartry of the Dublin Water-Works, is sixty-six feet high at its deepest part, and the greatest depth of water, sixty feet. It is 1,640 feet long on the top, and twenty-eight feet wide, which forms a public road. The base, at the deepest part, is 380 feet wide; the inner slope being 3 to 1, and the outer slope 2½ to 1,

and the total quantity of earthwork in it is 320,000 cubic yards. The puddle wall in the embankment is six feet wide at the top (one foot below the top bank), and eighteen feet wide at the level of the old river bed. It was carried, for its entire length, down into solid rock.

The dam of Bradlee basin, Boston, is 2,000 feet in length, twenty feet wide on top, one hundred and fifty feet at the base, and greatest height thirty-five feet. In the center of the bank is a puddle wall ten feet thick at the base, and four feet at the top, founded on the rock. The earth embankment was laid in layers, well watered and rolled.

COMPARISON OF LARGE GRAVITATION WORKS.

	DISTANCE OF SOURCE IN MILES	NO. ACRES OF WATER SHED.	CAPACITY OF STORAGE IN GALLONS.	HEIGHT OF SOURCE ABOVE CITY DATUM IN FEET.	CAPACITY OF AQUEDUCT IN GALLONS.	POPULATION.
New York.....	40	216,844	9 billions	160	92 millions	1,216,500
Boston	16	100,000		134	86 "	412,000
Baltimore	7		765 millions	165	170 "	332,190
Liverpool		10,000	4 billions		17 "	600,000
Manchester....	18	19,390	6 "	790	39 "	750,000
Glasgow*	25¾	47,800	12 "		.50 "	550,000
Dublin	21.6	14,080	2½ "	692	20 "	330,000

* Gorbals not included,

The dam for diverting the waters of Gunpowder Falls, for supply of Baltimore, is built of rubble and white marble upon solid rock. Thickness at base is sixty-two feet; depth of foundation below original surface is thirteen feet; width of the overflow is three hundred feet. The wings extend into the hill on each side two hundred and fifty-six feet. The height from the extreme foundation to the overflow is twenty-nine feet. The filling of the clay and earth on the inside is forty-five feet at the base.

Liverpool, Eng., designs constructing a masonry dam, at the source of the new supply in Wales, eighty-four feet in height.

PUMPING SYSTEM.

The divisions of power are:

Wind Power. Water Power. Steam Power.

And the methods of supply by:

Reservoir. Stand Pipe. Direct or Holly Plan.

The value of a pumping system recommends itself on the point of economy in construction, for the outlay is in proportion to the existing necessities, which can be increased as the demands require. The original water consumers are not, therefore, taxed so heavily for future exigencies of gravity works. This idea can be better illustrated by the comparative cost of construction and maintenance of gravitation and pumping works:

	BALTIMORE GRAVITATION.	CHICAGO PUMPING.	BOSTON GRAVITATION.	CINCINNATI PUMPING.
Available capacity for daily supply....	200 millions	120 millions	86 millions	36 millions
Largest daily consumption in 1880....		73 "	28 "	38 "
Total valuation of works	10 "	8.8 "	18 "	7 "
Bonded indebtedness.	9 "	3.9 "	12 "	1.6 "
Annual interest..................................	440 thousands	283 thousands	619 thousands	108 thousands
Annual current expenses..................	87.5 "	206 "	211 "	200 "
Annual maintenance, including interest at 5 per cent on total valuation of works.	587.5 "	646 "	1,111 "	50 "

The reservoir system is the most preferable of the three methods, when natural elevation can be secured, for the pumping service is distinct from the distribution; and, where reservoirs of large capacities are obtainable, a closer margin for reserve pumping power can be adopted, besides a storage reservoir provides for contingencies that may arise, and allow cessation of pumping during the turbidity of water source, caused by sudden freshets.

The stand-pipe is adopted where the elevated grounds are not sufficient for reservoir purposes, to give a desirable water pressure; or where reservoirs may not be desired, but to secure the

head and provide for a constant and reliable action of the pump that is not obtained by a direct system.

The direct system, commonly called the Holly Plan, does away with reservoir and stand pipe, and delivers the water directly into the mains under a pressure usually fifty pounds per square inch for domestic use, which is increased to one hunded pounds when fires occur. In the Holly Plan, a reserve power is used for fire purposes, besides mechanical device for regulating and controlling the variable pressure.

In either the stand pipe or direct system, a reserve power should be provided equal to the largest daily consumption.

From a compilation of general information concerning water-works of the United States and Canadas, published by the Holly Manufacturing Company in 1878, we arrange the following:

188	cities and towns	use steam-power	for water supply.
104	"	have gravity works	"
32	"	use water-power	"
10	"	have gravity and steam works	"
27	"	use steam and water-works	"
2	"	have gravity, steam, and water-powers	"

Of the above number of pumping works—

139 have reservoir system.
98 have direct system.
16 have stand-pipe system.
4 have direct and reservoir combined.
1 has the three systems combined.
1 has stand-pipe and direct combined.

The expense of pumping water by steam and water-powers, also the practical yearly duties of various pumping engines, are given in the tables on pages 61 and 64, compiled from annual reports for 1880:

PRACTICAL DUTIES (WITHOUT DEDUCTIONS) OF PUMPING ENGINES (YEARLY AVERAGE).

(*From Annual Reports of* 1880.)

	NON ROTATIVE.		ROTATIVE.			COMPOUND.		MISCELLANEOUS
	WORTHINGTON.	CORNISH.	HOLLY.	LOW PRESSURE.	HIGH PRESSURE.	LEAVITT.	MISCELLANEOUS.	
Louisville, Ky.		44189515						*20280502
		45544384						19572536
Brooklyn, N. Y.				59550000				
				56004900				
				68378000				
Albany, N. Y.							70991413	
							70327595	
Toronto, Canada	38477080							
	38726890							
Toledo, O.	36399973							
Boston; high service	51063000							
Charleston, Mass.	52845400							
Columbus, O.			28758135					
Chicago, north side				52956684				
Chicago, west side							58808495	
Phila., Schuylkill		24342000					49726000	
		35360000					55633000	
Phila., Belmont	30000000							
	37900000							
	44870000							
Phila., Delaware					39000000			
Phila., Roxborough	38280000	36280000						†28380000
Phila., Frankfort	27000000						57160000	
Lawrence, Mass.						98583176		
Dayton, O.			15000000					
Cleveland, O.	42397185	30361497					29558769	
		31925636						
Lynn, Mass.						92843506		
Pawtucket, R. I.								‡96046816
Lowell, Mass.	59112831						76108012	
Cincinnati, O.					44304907			
				38014283	38953517			‖21665474
					45886944			

REMARKS.—* Blake pump; † Knowles; ‡ Corliss; ‖ Low pressure, direct acting.

The term, duty of a pumping engine, is a conventional one, used by engineers to measure the relative merits of performance, or effective work, expressed by the ratio of product in foot pounds of the weight water into the height it is lifted, to one hundred pounds of the coal consumed to lift the water. The following tables of expert trials are taken from "Manual for Engineers and Steam Users," by John W. Hill, M. E. (1878), with a few additions:

PERFORMANCE OF PUMPING ENGINES.

LOCATION.	DATE.	ENGINE.	DESIGNER.	DUTY FOR ONE HUNDRED POUNDS COAL.	CAPACITY.	AUTHORITY.
United Mines, Cornwall	Sept. 1842	Cornish single cylinder, jacketed	Taylor..........	114,361,700*	....	Pole.
Carn Brea, Cornwall..	1841	Cornish compound, jacketed...	James Sims.....	101,702,000*	....	Pole.
Lynn, Mass..........	Dec. 1873	Compound beam and fly-wheel, jacketed..................	E. D. Leavitt...	103,923,215	4,938,528	Experts' Contract Trial.
Lowell, Mass.........	June 1875	Compound beam and fly-wheel, jacketed..................	Simpson........	117,350,100*	....	Evans' Annual Report.
Lawrence, Mass	May 1876	Compound beam and fly-wheel, jacketed..................	E. D. Leavitt...	96,201,900	Each eng'e 4,979,234	Experts' Contract Trial.
Trenton, N. J........	Mar. 1876	Compound beam and fly-wheel, jacketed..................	Wm. Wright....	84,500,000	2,086,523	Slade.
Milwaukee, Wis......	May 1875	Compound beam and fly-wheel, jacketed..................	R. W. Hamilton.	76,955,520	Each eng'e 8,683,720	Experts' Contract Trial.
Marion, Ind..........	Feb. 1877	Single cylinder yoke and fly-wheel condensing.........	Dean..........	49,231,207	Two eng'es cupled 1,500,000	Cook.
Haarlem Meer, Holland	June 1848	Compound beam annular cylinder....................	Gibbs & Dean..	80,000,000*	200,000,000	Appleton's Dictionary.
Chicago.............	Dec. 1874	Single cylinder beam and fly-wheel unjacketed.........	D. C. Cregier...	65,824,581	Two eng'es cupled 36,000,000	Experts' Contract Trial.
Chicago.............	April 1877	Compound beam and fly-wheel, unjacketed...............	Quintard Works.	West engine 99,082,300	16,160,470	Experts' Contract Trial.
Chicago.............	April 1877	Compound beam and fly-wheel, unjacketed...............	Quintard Works.	East engine 96,066,800	15,571,970	Experts' Contract Trial.
Chicago.............	April 1877	Compound beam and fly-wheel, unjacketed...............	Quintard Works.	75,000,000	....	Theron Skeel.
Cincinnati...........	Nov. 1872	Horizontal crank and fly-wheel, two engines coupled, non-condensing..............	Shield.........	43,566,178	4,702,805	Hermany.

* Said to be average duty; all others obtained by special tests.

The capacity is stated in delivery of gallons per day of twenty-four hours.

PERFORMANCE OF PUMPING ENGINES.

LOCATION.	DATE.	ENGINE.	DESIGNER.	DUTY FOR ONE HUNDRED POUNDS COAL.	CAPACITY.	AUTHORITY.
Cincinnati	Nov. 1872	Vertical single cylinder crank and fly-wheel condensing	Scowden	37,789,990	4,651,987	Hermany.
Cincinnati	Nov. 1872	Vertical single cylinder crank and fly-wheel condensing	Scowden	34,064,977	4,263,297	Hermany.
Cincinnati	Nov. 1872	Vertical direct acting single cylinder condensing	Shield	23,580,687	11,847,481	Hermany.
Louisville	1873	Cornish	Scowden	37,536,730*	3,816,575	Journal American Society Civil Engineers.
Newark, N. J.	1870	Compound duplex	Worthington	77,157,840	....	Bailey.
Cleveland, O.	1873	Cornish	Allaire Works	41,774,955*	5,711,988	Journal American Society Civil Engineers.
Jersey City	1856	Cornish	W. Point Foundry	72,115,396	....	Copeland & Worthen.
Charleston, Mass.	1872	Duplex	Worthington	56,937,643*	....	Journal American Society Civil Engineers.
Providence	1874	Radial cut off	Geo. H. Corliss.	25,865,000	....	Smith, Graff & Reynolds.
Providence	1874	Compound duplex	Worthington	53,528,210	....	Smith, Graff & Reynolds.
New Bedford, Mass.	1869	Beam and fly-wheel	McAlpine	59,336,497	....	Hoadley & Francis.
Brooklyn, No. 1	1860	Single cylinder beam	Wright	60,798,200	15,439,653	Smith, Graff & Worthen.
Cleveland, O.	1875	Compound duplex	Henderson	31,968,006*	8,400,000	Annual Report.
Cincinnati, O.	Mar. 1879	Compound direct acting	Warden	53,957,957	2,000,000	Hill.
Columbus, O.	Feb. 1876	Crank and fly-wheel, four engines coupled	B. Holly.	24,045,951	....	
Pawtucket, R. I.		Compound beam and fly-wheel, steam jacket	Geo. H. Corliss.	133,522,090	....	Contract Trial.
Buffalo, N.Y.	1879	Holly, four cylinders, with fly-wheel	Holly Co.	86,176,315	6,502,000	Park Benjamin.

*Said to be average duty; all others obtained by special tests.

The capacity is stated in delivery of gallons per day of twenty-four hours.

COST OF PUMPING ONE MILLION GALLONS OF WATER.

(*From Annual Reports*, 1880.)

CITY.	MILLIONS OF GALLONS PUMPED.	AVERAGE LIFT IN FEET.	COST OF COAL PER TON.	COST OF PUMPING ONE MILLION GALLONS.					COST PER MILLION ONE HUNDRED FT. HIGH.	REMARKS.
				FOR WAGES.	FOR COAL.	FOR REPAIRS.	FOR STORES.	TOTAL.		
St. Louis, Mo.....	9944	50.	$2.66	$1.57	$2.85	$ .15	$ .18	$ 4.75	$ 9.50	Low service.
St. Louis, Mo.....	9857	225.	2.66	3.17	8.19	.31	.36	12.03	5.34	High service.
Charleston, Mass..	3434	150.8	4.81	2.03	5.73	.09	.30	8.15	5.40	
Boston, Mass.	856	116.4	5.07	4.32	4.82		.47	9.69	8.30	High service.
Philadelphia, Penn.	13232	124.	3.34	2.64	3.72	.41	1.49	8.27	6.68	Steam.
Philadelphia, Penn.	7887	100.	3.34	1.33	10	.35	.20	1.98	1.98	Water.
Columbus, O.	912	175.	1.37	8.10	3.48	.16	.41	12.15	6.90	Holly.
Chicago, Ill.......	12354	104.	4.00	1.73	3.36	.10	.49	5.68	5.42	North works.
Chicago, Ill.......	8648	98.	3.60	2.32	2.67		.36	5.15	5.24	West works.
Dayton, O........	387	127.	2.70	16.68	8.88			28.36	22.33	Holly.
Brooklyn, N. Y...	11196	163.	4.40	3.03	5.27			10.84	6.65	
Pawtucket, R. I...	325	262.	4.86	7.57	5.51		.50	13.58	5.17	
Toledo, O	1193	160.	2.28	4.32	4.63			9.25	5.77	
Montreal, Can....	3095	165.						1.98	1.20	Water.
Montreal, Can....	452	165.		7.28	8.85	3.02	1.05	20.20	12.53	Steam.
Lowell, Mass.....	771	165.	4.40	3.07	4.25	.20	.32	7.84	4.73	Morris engine.
Lowell, Mass.....	52	166.	4.40	3.74	5.54		.20	9.48	5.69	Worthington engine.
Cincinnati, O.....	2325	171.	2.79	6.53	5.38	2.06	.40	14.37	8.40	Low service.
Cincinnati, O.....	4959	245.	2.86	4.00	7.66	1.59	.42	13.67	5.58	Middle service.
Cincinnati, O.....	563	293.	3.15	12.50	8.49	2.69	.65	24.33	8.30	High service.

STAND PIPE.

New York has a stand-pipe, for high service use, 170 feet high.

Cleveland has a stand-pipe 148 feet high, 36 inches in diameter.

The stand-pipe at Louisville is 48 inches in diameter, 132 feet high, made of ¼ to ½-inch wrought-iron plates, the whole incased in wood.

The Mt. Auburn High Service at Cincinnati is supplied by two wrought-iron tanks (which answer the same purpose of stand pipes), each 60 feet in diameter and 38 feet high, and made of wrought-iron sheets 50″ by 140″, ¼″ to 7-16″ in thickness. The water surface is 483 feet above low water. The cost of each tank was $15,000.

The water-tower at Toledo consists of a wrought-iron stand pipe, around which is built a masonry structure of solid stone-work 36 feet square, commencing 16 feet below the natural surface, with a vertical thickness, under base of stand-pipe, of 7 feet; thence, with octagonal opening around the pipe, to a point near 3 feet above the surface of the ground, at which point its inner diameter is 16 feet, and outer dimensions 30 feet square. From this point, to a further height of four feet, the wall is composed of ashlar-face and brick backing; thence to a point 70 feet above the foundation of solid brick-work with octagon interior and exterior squares, the corners terminating in buttress walls; the top to be octagonal battering to an external diameter at the top of 14 feet. The total height is 224 feet, and the cost about $25,000.

A steel plate stand-pipe designed by J. D. Cook, civil engineer for Springfield, Ohio, is in course of erection by the Stacey Manufacturing Company of Cincinnati, which will be 112 feet high, 30 feet in diameter, thickness of lower ring being 25-32″, and upper ring 3-16″. The estimated cost is $35,000.

The stand-pipe of Southwark and Vauxhall Water-Works, London, is 178 feet high, made of three columns of cast-iron pipe, the center one extending 50 feet higher than the other columns. The side pipes are 30 inch, and center 48 inch in

diameter. The Grand Junction works, London, has a similar structure of two columns 153 feet high, incased in a brick structure.

The stand-pipe of East London Co. is 240 feet high and 3 feet in diameter.

HUSBAND'S PATENT BALANCE VALVE.

This patent is designed to supersede the costly stand-pipe. Fixed vertically, as near to the engine as practicable, is a strong casting provided with two short-flanged branches, the lower one being connected with the discharge outlet from the pumps, and the upper one with the delivery main. Between these branches a gun-metal valve of the double-seat description is placed, and is connected to an additional water-tight hat working on the top of the valve-seating. The seating is firmly held down by bolts passing through it and fastened to the casing. A ram lined with gun-metal, and of the same diameter as the upper valve, is secured water-tight into it by a colter, and works vertically up and down, passing through a stuffing-box packed with cup leather, bolted to the upper portion of the casing. The head of the ram works in a cross-guide lashed with gun-metal, and supported by four strong vertical pillars. The ram is loaded with weights nearly equal to the minimum load of the engine; the lowest weight is provided with lugs working loosely over the vertical pillars, which are provided with adjusting nuts and leather washers, for the purpose of preventing the valve from falling heavily and injuring its seating. The action of the apparatus is as follows: The water, on entering the casing from the pumps, acts upon the under side of the upper valve. The area of the valve is the same as that of the ram, which, being loaded somewhat under the working load of the engine, is immediately lifted, raising the valve with it, and thus giving the water free access to the delivery main.

In the event of the main being fractured at any point beyond the valve, the pressure within the main is suddenly reduced on account of the great escape of water, and is, consequently, unable to support the loaded valve, which immediately closes;

thus the working load of the engine is retained, and the possibility of accident by racing prevented.

FUEL EXPENSE FOR PUMPING COMPARED ON DUTY BASES.—(*Fanning.*)

DUTY IN MILLION FOOT POUNDS.	NUMBER MILLION GALLONS PUMPED DAILY, ONE HUNDRED FEET HIGH. COAL IN FURNACE AT $8 PER TON.						
	1	2	3	4	6	8	10
100	$1,277.86	$2,556	$3,834	$5,111	$7,667	$10,223	$12,779
90	1,419.85	2,840	4,260	5,679	8,519	11,359	14,198
80	1,597.32	3,195	4,792	6,389	9,584	12,778	15,973
70	1,825.51	3,651	5,477	7,302	10,953	14,604	18,255
60	2,129.76	4,260	6,389	8,519	12,779	17,038	21,298
50	2,555.72	5,111	7,667	10,223	15,334	20,446	25,557
40	3,194.65	6,384	9,584	12,769	19,168	25,537	31,946
30	4,259.53	8,519	12,779	17,038	25,557	34,076	42,595
20	6,389.30	12,768	19,168	25,537	39,336	51,174	63,893

DIMENSIONS AND COST OF CONSTRUCTING PUMPING ENGINES.

CITY.	WHEN BUILT.	KIND OF POWER.	MAX. CAPACITY IN MIL. GAL.	DIAMETER OF STEAM CYLINDER IN INCH.	STROKE IN FEET.	DIAMETER AND STROKE OF PUMPS.	COST.	REMARKS.
						" '		
Chicago.....	1876	Compound condensing beam and fly-wheel.	30	48 H. P. 76 L. P.	6 H. P. 10 L. P.	51 × 10	$543,500	with 6 boilers.
"	1857	Low-pressure beam and fly-wheel single eng	13	60	10	40 × 6¼	59,000	" 2 "
"	1867	Double engine beam and fly-wheel.	18	44	8	28 × 8	112,500	" 1 boiler.
"	1872	Double engine beam and fly-wheel.	36	70	10	57 × 10	188,400	" 3 boilers.
"	1853	Single engine beam and fly-wheel.	7½	44	9	34 × 5½	24,500	" 1 boiler.
Cincinnati.	1850	Single engine fly-wheel.	4½	45	8	18 × 8	30,000	with 60 ft. iron col.
"	1865	Single engine direct acting.	20	100	12	46 × 12	200,000	
"	1874	Double engines fly-wheels and beams.	7½	28	8	25½ × 8	99,000	Plunger 16½ "
"	1869	Double horizontal engines, fly-wheel.	4	18	5	13¼ × 5	18,000	with 1 boiler.
"	1874	Compound dir't acting.	2	14 H. P. 22½ L. P.	2½	10 × 2½	8,600	
St. Louis...	1875	Double, with beam and one fly-wheel.	25	50 H. P. 80 L. P.	7¼ H. P. 11½ L. P.	45¼ × 8½	280,000	Plunger 32" dia.

CHAPTER V.

HISTORICAL AND STATISTICAL.

New York was supplied by dug wells until 1842, when the Croton water was brought, by gravitation, into the city, through a brick aqueduct, thirty-eight miles in length, crossing the Harlem River by "High Bridge." The area of the water-shed of the Croton is 338.82 square miles. The storage capacity nine billion gallons. The capacity of the aqueduct is ninety-two millions of gallons per day.

There are three distributing reservoirs:

One of	150	million.	
One of	1200	"	in Central Park.
One of	24	"	
One of	10¾	"	for high service.

The population is 1,206,500; miles of water-pipe, 500—the largest being seventy-two inches in diameter; the average daily consumption of water ninety-five millions; number of taps, 77,000. All buildings are assessed by frontage-tax besides usual water rates. The meter rate is 7½ cents per thousand gallons.

The original cost of the gravitation works was about nine millions; present water-works valuation is thirty-two millions.

An additional supply from Bronx River is now in course of construction. The water will be conducted through an aqueduct, of forty-eight inch cast-iron pipe, twenty miles in length. During last summer a water-famine was prevented by a Providential rain-fall.

Philadelphia was supplied with water, systematically, in 1801; previously, wells were the only source.

The system of supply is pumping by steam and water-power, thirty-seven per cent. being done by the water-wheels in 1880.

The available capacity of water-wheels is 36,000,000 gallons daily. During summer there is a deficiency of power. Capacity of all the pumps 71.8 million gallons. There are 16 reservoirs, with a total capacity of 200 millions. The distribution of water is divided among the various works in relation to respective ele-

vation. The population, in 1880, was 846,984. Miles of pipe, 746. Daily average consumption, in 1880, 57.7 millions. Largest daily consumption 80½ millions. Number of meters 30. Total receipts, in 1880, were nearly 1½ millions of dollars; and expenditures nearly $400,000. Laying of water-pipes assessed on abutting property. Total profits, since 1855, over twelve millions of dollars.

The pumping stations and performance for 1880 are:

STATIONS.	PER CENT OF WATER PUMPED IN 1880.	LIFT IN FEET.	SOURCE OF SUPPLY.	POWER.
Fairmount, water-power.	37 35	90	Schuylkill River	7 Turbine water-wheels.
Schuylkill, steam-power.	25.96	120	" "	2 Cornish and 2 Compound Engines.
Belmont, " "	16.78	207	" "	5 Worthingtons.
Delaware, " "	9.45	133	Delaware "	1 Worthington, 1 low, 1 high pressure.
Roxborough, " "	5.52	346	Schuylkill "	1 Cornish, 1 Worth, and 1 Knowles
Chestnut Hill," "	.02	125	"	1 horizontal high pressure.
Frankford, " "	4.50	203	Delaware "	1 compound and 1 Worthington.

Brooklyn.—Water-works introduced in 1859. The system is by pumping, with reservoir distribution. The source is the southern slope of Long Island Sound, ten to twenty-two miles from East River. The water is gathered from a drainage area of 60½ square miles by intercepting ponds, and conducted, through masonry conduit, to the pump well, seven miles from East River. The natural flow, from these ponds, into the conduit being insufficient during summer time, pumping engines were erected, 1874, at Watts' and Smith's ponds to meet the deficiency.

The storage reservoir, built in 1873–'76, has a water surface of 250 acres, and a capacity of one billion gallons. There are three low-pressure beam-engines, with a combined capacity of 44 millions daily. The distributing reservoir is 3,400 feet from pumping wells, at 163 feet elevation and with a capacity of 160 millions.

Population, in 1880, was 566,689. Miles of pipe, 351. Daily average consumption of water, in 1880, 30¾ millions. Largest

daily consumption 48 millions; number of taps, 60,000; meters, 859; original cost of works, $5,200,000.

Chicago.—The first works were constructed by the Chicago City Hydraulic Company in 1840, Lake Michigan being the source. The superiority of this water, as compared with well water, so manifested itself during the cholera of 1849–'50 that the works became a public institution, under whose control they were enlarged, in 1854, after plans of Wm. J. McAlpine, C. E. The system is constant pumping through stand-pipe distribution, 120 feet above city datum. There are two pumping stations—North Side and West Side—the latter being the new works, erected in 1874. The source is Lake Michigan. Previous to 1867 the intakes were near the shore; and, in order to secure pure water, a brick tunnel, five feet wide by five feet two inches in depth, was built under the lake, a length of two miles, to a crib located in the lake. A second tunnel, 5 ft. in diameter, parallel to the first, and forty-six feet apart, was constructed to the North Side Works, thence continuing under the city, a distance of 20,000 feet, to the West Side Works. The North Side Works has four engines, with a combined capacity of 64 millions; and the West Side Works two engines, with a capacity of 46 millions.

In 1856 a twenty-four inch wrought main was laid in the Chicago River; but, before brought into use, was injured by pile-driving, and had to be relaid. In 1869 all the submerged mains were abandoned, because of frequent accidents, and brick tunnels, six feet in diameter, were built under the river. The statistics for 1880 were: Population, 503,304; miles of pipe, 450; daily average consumption, 57.4 million gallons; number of meters, 2,000. Cost of West Side Works, with new tunnel, $1,600,000. Total cost of works, $8,644,000.

Boston.—In 1835 there were 2,767 wells in use, thirty-three of which were artesian, besides a water-works under the control of "The Aqueduct Corporation." Out of the whole number of wells only seven furnished water soft enough to use for washing. In 1840 there was great complaint of the deficiency of wells, and in one case it was stated that a well from which

many drew their water, was kept locked except at certain hours. During this time there were 56 reservoirs, each holding 300 to 400 hogsheads. In 1848 water was first introduced from Lake Cochituate, through a brick conduit (except the cast-iron syphon over Charles River), oviform in shape, large end down, 6.33 feet high and 5 feet wide. Its length is 14.627 miles, with a total fall of 4.26 feet. It has a capacity of delivering 16 million gallons daily, with a velocity of one foot per second. The area of water surface, at full water, of Lake Cochituate is 800 acres; when drawn down 10 feet or level of the flow line of conduit, the area is 489 acres. Elevation is 134.36 feet, and bottom of conduit at dam 121 feet above tide level. There are two granite dams 500 feet apart. The first dam was built on quicksand, and after filling of the lake, springs boiled up and washed away the sand.

The new supply from Sudbury River was inaugurated in 1878. The drainage is 78.24 square miles. The conduit is 16 miles long, with a grade of 1.056 feet per mile. It is built of concrete and rubble masonry, lined with brick. It crosses the Charles River by granite bridge 475 feet long and 75 feet high. Its sectional area is 56.75 square feet, and capacity 70 millions daily.

There are two earth embankment reservoirs, one of 120 millions and the other of 550 millions capacity, besides four stone masonry structures of 22 millions capacity combined. One of the latter is used for high service, is 219 feet above tide, and has a capacity of 7 millions. The Roxbury High Service is supplied by two 20″ by 36″ pumps, through a stand-pipe 5 feet in diameter and 80 feet high. There is also a couple of temporary high service works. There are several cast-iron syphons of 20 and 24-inch pipes, with ball and socket points, submerged in the rivers. A crack in one of these 20-inch pipes was stopped by pine wedges, and then covered with an india-rubber band, secured by iron clamps. The work was done by a diver, and occupied three weeks. The Mystic Water-Works, of Charleston, became a part of the Boston Water System in 1873, by annexation.

The population is 412,000; miles of pipe, 500; daily average consumption, 36 millions; number of water takers is 68,334. There are 1,313 meters in use. The value of the works to December, 1880, was $18,354,716.17.

St. Louis.—The first water-works was built at foot of Bates Street in 1830, eight years after it became an incorporated city. The old works were entirely abandoned in 1872, when the new works, built after the design of Jas. P. Kirkwood, civil engineer, were put in operation. The new pumping stations is at Bissell's Point at the northern city limit. The water is taken from Mississippi River, through a cast-iron tower (arranged to take water at any level) sunk in the river to the bed rock, and conducted by a 66-inch iron pipe to the first or low service pumps, which raises the water from 15 to 50 feet, according to the stage of the river, into settling basins (four in number, each 25 millions capacity); from thence it flows through a brick conduit 1,100 feet long, to the clear well of the high service or main works. The clear water is pumped through a stand pipe into a reservoir on Compton Hill, 870 feet by 540 feet, and 22 feet deep, and 176 feet above city directrix. The low service works has two Cornish bull and one rotative engine, and the main works has three combination beam engines with a combined capacity of 40 millions of gallons daily. The sediment in the water amounts, at times, to 1.8 per cent. of the total bulk. Nine hundred and forty-four parts in one thousand of the sediment is deposited within twenty-four hours in still water. One of the old reservoirs was abandoned entirely for twelve years, on account of the accumulation of deposit, being 30 feet in depth. It was cleaned by hydraulic mining, after a method designed by Henry Flad, civil engineer.

The population by last census is 350,522; miles of pipe, 200; daily consumption, 25 millions; number of taps, 20,000.

The cost of the new works was about five millions of dollars.

Baltimore.—In 1814 an association was formed for the purpose of introducing a copious supply of wholesome water into the city from Jones' Falls. The works were purchased by the city in 1854 for $1,350,000, and enlarged in 1857-'62. The

river water is diverted into Lake Roland, an artificial lake of 116 acres water surface. From this reservoir it is brought through an elliptical conduit, 3.62 miles, and discharged into Hampden Reservoir. This reservoir is semicircle in form, 1,000 feet diameter, with a water surface of 8 acres. It is 217 feet above tide. From this point the water flows through three lines of 30-inch cast-iron pipe, 7,100 feet in length, into Mt. Royal Reservoir, which is a circular structure 550 feet in diameter with a water surface of 5 acres, and 150 feet above tide. This reservoir supplies that portion of the city below 112 feet elevation. The Hampden Reservoir supplies the districts between 112 feet and 188 feet above tide, and the high service reservoir the district between 188 feet and 320 feet above tide. In 1867 the Druid Lake was constructed with a view of storing clear water, to be used when Lake Roland was muddy. It is made by building an earthen dam (across a natural valley in Druid Hill Park), 119 feet high in the middle with a puddled wall in the center 36 feet wide at the bottom. The greatest depth of water is 63 feet. Seven lines of cast-iron pipe were originally laid under the embankment, but broke within two years. Five lines of 30-inch pipe were then laid through a cut-in rock. Its capacity is 493,000,000 gallons, with water surface of 53 acres. The high service reservoir is circular, 500 feet diameter, 20 feet deep, and 350 feet above tide, and supplied by two Worthington pumps.

The new supply from Gunpowder River is brought through a 12-foot conduit 7 miles in length, having a capacity of 170 million gallons, to Montebello Reservoir, of 80 acres water surface, and 163 feet above tide. From here it is conveyed partly in tunnel and in open cut 5,391 feet to Lake Clifton, which has a water surface of 30¼ acres and elevation 163 feet above tide, and 31 feet deep. Provisions are made for six 40-inch mains; two now being used. The new system cost $4,704,260.83, and was formerly inaugurated in October, 1881. The statistics for 1880 are: population, 332,190; miles of pipe, 277; water takers, 49,000; meters, 524; outstanding bonds amounting to 9 million dollars.

Buffalo takes its supply from a pier in Niagara River, and is conducted through a tunnel 22½ feet below the river bottom. The system is pumping and reservoir distribution with Holly plan for fire purposes and supply of higher levels. At the pumping station there are two Worthingtons—one of 10 million and the other of 15 million capacity—and a condensing beam engine of 8 million capacity. A third Worthington is now in course of erection. There are three Holly pumps, one of 1½ millions; one of 2½ millions; and one of 6 millions capacity, which take their supply from the face main 20 feet below the reservoir, and pump directly into the mains. The statistics for 1880 are: population, 155,137; miles of pipe, 102; daily consumption, 16½ million gallons; water-takers, 9,099. The original cost of the works was $400,000. Present value 3 million dollars, outstanding bonds $2,950,000.

Washington is supplied from the Potomac River by diverting the waters at Great Falls 17 miles above the city, by a dam of cut masonry with rip-rap backing. Its top is 148 feet above tide level at Washington. The water is conducted through a brick aqueduct 9 feet in diameter, with a grade of 0.75 feet per mile. The reservoir at Powder Mill Branch (made by damming the stream), has a water surface of 50 acres, with a capacity of 176 million gallons. The expectation that the Potomac water, which is frequently very muddy, would have time to settle in this reservoir before being drawn from its outlet was not realized in consequence of the turbidity of drainage water collected by the reservoir itself; a connecting conduit was therefore built in 1864 to supply direct from Potomac River, during freshets, in Powder Mill Branch.

The high levels of Georgetown or those more than 90 feet above tide level, are supplied by pumping and reservoir distribution. The reservoir is a hemispherical brick structure, 120 feet in diameter, and 220 feet above tide.

The statistics for 1880 are: population, 147,307; miles of pipe, 175; daily consumption of water, 26 million gallons; number of taps, 17,000. Cost of aqueduct and its maintenance to

June 30, 1880, was 3.8 million dollars, and for water mains, 1.7 millions.

Louisville.—The Louisville Water Company was chartered in 1854, and in 1856 the city subscribed to the capital stock to the amount of $550,000. The supply is taken from the Ohio River, 1½ miles above the city limits. The intake is 300 feet from shore, 50 feet in diameter, made of a crib of timber filled in with stone, the mouth of the inlet being 5 by 12 feet, and set 1 foot below lowest stage of water. By 1865 the inlet pipe was half full of silt; in order to clean it a well was sunk over the pipe, 105 feet from its end, the pipe cut, and then cleaned out. In 1877 the pipe was again cleansed. Anchor ice has given them much trouble. There are two Cornish beam engines which deliver the water through a wrought-iron stand pipe, 48 inches in diameter and 132 feet high, into a reservoir of earth embankments, 141 feet above low water, and 3,650 feet from the works. The water surface of this reservoir is 178 by 374 feet. The new reservoir on Crescent Hill is 175 feet above low water, and 2½ miles from stand-pipe. It has a capacity of 100 millions. Notwithstanding extraordinary care having been taken in the foundations of this reservoir, leaks and slips occurred soon after it was filled.

The statistics for 1880 are: Population, 123,645; miles of pipe, 110; daily consumption of water, 5½ million gallons; number of meters, 201; hydraulic elevators, 50; value of the works—construction, $800,000; enlargements, $2,400,000; total, 3.2 million dollars.

San Francisco is supplied by the Spring Valley Water Company from three sources. One from Lobos Creek, 4 miles from the city, where the water is gathered after slow percolation through sand, and conducted through 23,700 feet of wood and masonry aqueduct to the pumping-works (at zero datum of city level) at Point Black. These engines raise the water into two reservoirs on Russian Hill, respectively 396 feet and 139 feet above city datum. The ordinary yield of the source is 2¼ millions daily. Another source is from the mountains of San Mateo County, 15 miles from San Francisco, where a dam was

built in 1864, 640 feet long, 26 feet wide on top, 95 feet high, with slopes 2¾ and 2½ to 1 foot. A puddle-trench is sunk 26 feet below the natural surface to the rock. After the reservoir was full, a leak appeared at one end of the dam caused by an unsound rock. While the reservoir was full a shaft was sunk 80 feet deep to the point, and the rock removed and replaced with puddle. This reservoir is 46 feet deep, and has a capacity of 1,083 million gallons, with a water surface of 692 feet above the sea. The water is conducted 13 miles, through a flume partly of 30-inch wrought-iron pipe, to Lagunda Honda Reservoir, 377 feet above the sea, with a capacity of 33 million gallons.

The third supply is brought from the water-shed of Lock's Creek, 2.75 square miles in area, and 505 feet above tide. This water is conveyed 17.42 miles to St. Andres Reservoir through wrought-iron pipes and tunnels lined with solid masonry.

The St. Andres Reservoir has a capacity of 7,000 million gallons, and is formed by an earth dam 640 feet long, 25 feet wide on the top, and 93 feet high, with a puddle-trench 47 feet more to the rock. The cost of the works to 1875 was $8,746,928.12. Amount paid on dividends to stockholders $4,701,562.18.

The population in 1880 was 233,956, and daily consumption of water 17 millions.

Cleveland.—The water-works were constructed in 1853 after the plans of T. R. Scowden, civil engineer. The system is pumping through stand pipe with reservoir distribution. The source is Lake Erie, where the water is taken through a crib located in lake, 1¼ miles from shore, and conducted through tunnel under lake to the pump wells. The pumping stations contains two Cornish, a "Henderson" compound duplex, and a 10 million Worthington. The combined capacity is 28 million gallons. Another Worthington engine is being added to the service. The stand pipe is 148 feet high and 36 inches in diameter. The reservoir is made of earth embankments, 21 feet deep, with a capacity of 8 million gallons.

The population for 1880 was 160,142; miles of pipe, 125½; daily consumption of water, 10.18 million gallons.

Total cost of works to January 1, 1878, was $2,402,000. Bonded indebtedness, $1,725,000. Cost of original works, $523,000.

Portland, Maine, is supplied with water from Lake Sebago, which has storage capacity sufficient to supply the largest city of the world. The total area of water-shed is 520 square miles. The annual receipt of moisture, including rain and snow, is 51 billion cubic feet, while the discharge is 20½ billion cubic feet. The water is conveyed partly through a box conduit, 3′ 9″ by 3′ 6½′ an oval brick conduit 5,440 feet long, 2½′ by 3½′, to a gate-house, whence two wrought-iron mains, lined inside and covered outside with best quality Rosendale cement, each 16 miles long, distribute the water to the city. One of the mains is 20 inches in diameter for the whole length, the other 26 and 24 inches, and respectively 4 and 12 miles long. The water system is owned by the Portland Water Company.

Cincinnati.—The permanent system of water supply was commenced in 1817, when city council granted to the Cincinnati Manufacturing Company the privilege of supplying the city with water for ninety-nine years at an annual consideration of $100—the water to flow three feet above the first floor of James Ferguson's kitchen, on west side of Vine, between Sixth and Seventh Streets, by 1820.

The first water was drawn from a wooden penstock at Sycamore Street and Lower Market, July, 1821, being raised by horse-power from Ohio River at the present site of pumping works, and forced into a wooden reservoir, and from thence delivered through wooden pipes to water consumers.

The Cincinnati Manufacturing Company transferred its privileges, in 1820, to Samuel W. Davis, and by him sold to Cincinnati Water Company in 1825. The entire works were purchased by the city in 1839, for the sum of $300,000, and consisted of 19 miles of wooden pipes, 3½ miles of iron pipe, reservoir in three compartments of 1,700,000 gallons capacity, two high

pressure pumping engines with a capacity of 4,200,000 gallons per twenty-four hours.

The management of the water department was vested first with a board of directors composed of one councilman from each ward. In 1847 this power was given, by act of legislature, to a board of three trustees elected by the people, and in 1876 the Board of Public Works was established, which assumed entire control of all the public works, including the water-works.

The city is supplied by pumping and reservoir system, with a main and two auxiliary pumping works, and four distinct reservoir or distributing services.

The main work is located on the bank of the Ohio River, and takes its supply through two stone aqueducts, each 100 feet in length. The western one is extended 60 feet further into the channel of the river by two 40-inch wrought-iron pipes.

The pumping engines at these works are—three double and three single engines with a combined theoretical capacity of 49 millions, with present available capacity of 32 millions. The oldest reservoir, built in 1850-'53, is a stone structure, entirely above the surface ground, made in two divisions 23 feet in depth; the eastern part being 163 by 116 feet, and western 180 by 116 feet. Its capacity is 5½ million gallons. The cost was $50,000; its elevation, 176 feet above low-water mark in the Ohio River. The largest reservoir is built in a ravine, where a masonry structure was erected 1,251 feet long, 120 feet high, 48½ feet in width at the bottom, and 25 feet on top. There are two compartments formed by a masonry wall 307 feet in length, 30 feet at the base, 10 feet on top, and 67½ feet extreme height. The upper part contains 57 millions, and the lower 43 million gallons, at 30 feet depth. The elevation of flow line is 235 feet above low water in the Ohio River. The cost was $1,660,000. The high service No. 1 supplies nearly two millions daily to the hill-tops, pumping into two iron tanks, each 60 feet diameter by 38 feet high, 310 feet above the pumping station level, through 2,700 feet of 20-inch and 4,501 feet of 16-inch cast-iron pipe. The cost of this service to 1881, with

forty miles of pipe, two pumping engines of six million capacity, tanks, etc., was nearly half a million dollars.

No. 2, high service, was started in June, 1881. About 15,000 gallons are pumped daily into an iron tank, thirty feet in diameter by sixteen feet high, temporarily erected on wooden supports sixteen feet high. The elevation of flow line of tank is 354 feet above the pump station.

Number of miles of pipe in use (1880)...........	189
Number of valves in use..............................	2,334
Number of branches or taps.........................	23,627
Number of meters.......................................	545
Number of hydraulic elevators.....................	318
Daily average consumption of water for 1880...	19,476,739
Population..	260,000
Gallons of water per inhabitant per 24 hours.	75
Largest consumption of water for one day, 1880.	27,951,391

The present value of works is $6,778,847.55, distributed as follows:

Hunt Street Pumping Works..................	$ 184,475.98
Front " " "	1,696,356.33
Third Street Reservoir and property.........	400,000.00
Mt. Auburn Tanks................................	35,000.00
Water Mains.......................................	2,706,864.58
Western Hill Supply, No. 2, High Service..	58,603.61
Garden of Eden Reservoir......................	1,670,225.55
Office Fixtures....................................	5,000.00
Markley Farm......................................	22,321.50

The amount of outstanding water-works bonds is $1,625,000.00.

The water-fund provides for the interest on the entire fund, and a sinking fund for $600,000 of bonded indebtedness. The department furnishes free water to the fire department and public buildings to the amount of $40,000 per annum.

The net water-rent receipts for 1880 were..... $499,857.36
Net expenses.................. $186,527.90
Net interest...................... 102,768.00 289,295.90
Net gain (applied to extension of mains)....... $210,561.46

Toledo established her water-works in 1873–'74, after plans of J. D. Cook, C. E. The water is taken from the Maumee River, through a hexagonal crib, made of two rows of piling, with the space filled with broken stone and coarse gravel, and conveyed, through wrought-iron pipe and five foot brick conduit five hundred feet long, to filter gallery of 19,000 square feet. The filtering material is 24 inches of broken stone, 6 inches of 2-inch gravel, 6 inches of 1-inch gravel, 6 inches of ½-inch gravel, 6 inches of ¼-inch gravel, and 24 inches of fine sand. Maximum depth of water is four feet. The filtered water is discharged into a clear-water reservoir by means of gathering drains and an effluent pipe, and thence to the pump well. There are two Worthington engines, each of five million capacity, pumping against a 260-foot lift, into a stand-pipe. The cost of the works to December 31, 1880, including interest, was $1,145,476.62; population, 50,143; miles of pipe, 46.87; meters, 40; taps, 1,616; daily consumption, 3,262,000 gallons.

London is supplied with water by the following companies:

NAME OF COMPANY.	SOURCE OF SUPPLY.	AVERAGE DAILY SUPPLY.	NO. HOUSES SUPPLIED.	ESTIMATED POPULATION.	CAPACITY OF SUBSIDING RESERVOIRS IN MILL. GALS.	FILTER BEDS. NO.	FILTER BEDS. AREA IN ACRES.	ENGINE POWER. NO.	ENGINE POWER. HORSE POWER.	ENGINE POWER. GREATEST LIFT IN FEET.
Kent Water Co..................	Chalk Wells.	6,828,700	43,901	250,000				16	1,291	314
New River Co....................	Lea River and other sources.	27,179,000	123,493	9[illegible]0,000	169	13	11¼	22	1,804	270
East London Co........	Lea & Thames Rivers	24,754,919	107,851	808,882	605	25	23	18	[illegible],475	335
Southwark & Vauxhall Co..	Thames River...	19,264,250	80,146	502,350	66	9	14½	11	2,000	360
West Middlesex Co	" "	10,468,138	47,039	352,792	57	5	8	12	1,461	195
Grand Junction Co............	" "	12,017,830	3[illegible],709	321,381	19½	4	7¾	11	1,820	180
Lambeth Water Co..........	" "	13,671,900	52,529	367,703	125	7	4	17	[illegible],460	380
Chelsea Water Co..............	" "	8,134,300	28,395	210,0[illegible]0		7	6¾	8	[illegible],025	175

The East London Company has its intakes further up the Thames than the other works, where pumping engines, of 750 horse-power, are capable of delivering ten million gallons daily, through a stand-pipe 240 feet high and three feet in diameter, into its subsiding reservoirs. It also takes its supply partly from the Lea River.

The West Middlesex Company is above Hampton, and two miles below the East London Company's works. The water is drawn from the river every day, whatever its state may be; but, in times of exceptionally foul water, the intake is reduced as much as possible.

Close to the West Middlesex Company is the Grand Junction works. Near the latter are the works of the Southwark & Vauxhall Company. And at Thames Ditton, two miles further down, are the Lambeth and Chelsea works.

The Kent Water Company takes its supply, exclusively, from deep wells in the chalk. The New River Company takes its supply chiefly from the Lea River. It has supplied a large portion of London, for two hundred and seventy years, through a conduit originally forty miles in length, which has been shortened by various cuts.

The statistics, as per monthly report for July, 1875, were: Population, 3,713,108; miles of pipe, 3,074; daily average consumption from Thames, 64,791,000 gallons: daily average consumption from other sources, 57,528,000 gallons. Total daily average, 122,319,000 gallons.

The Capital invested in the supply of water by these eight companies represents a total sum of $51,900,000.

The largest pumping engines in use, in 1875, were:

			STEAM CYLINDER.	PUMP.
			″ ′	″ ′
Single-acting beam-engine at Battersea works.			112×10	50×10
"	"	at Grand Junction.	90×11	38×11
"	"	at East London....	100×11	50×11
"	"	at East London....	85×10	43× 9

An act of 1871 provides power to compel the companies

to give constant supply when the public authorities may demand it.

By the act of 1872 a Government Inspector was appointed, who examines and reports monthly the condition of the works and the character of the water furnished.

As the London and Lea Rivers have been condemned by the Rivers Pollution Commission, as well as the shallow surface wells, of which they say, are not fit for human consumption, several schemes have been proposed for new or improved sources.

Mr. Bateman proposed to furnish a daily supply, equal to 220 million gallons, from the mountains of North Wales, where the annual rain-fall amounts from 70 to 150 inches. The cost was estimated at $51,000,000.

The plan proposed by Messrs. Hemans and Hassard is to gather the water from the mountains in Cumberland, where a supply equal to 250 million gallons daily can be secured for the sum of $61,000,000. The Rivers Pollution Commission were of the opinion, that an ample supply of wholesome water could be secured from the chalk wells and springs, within a radius not exceeding fifty miles of London.

Liverpool had in 1874, 493,405 inhabitants. It is supplied with water partly by gravitation and partly by pumping from deep wells in and near the city. The gravitation-works are situated on the slopes of Rivington Pike, a distance about 33 miles. One-third of the storage water is required for compensation purposes. The area of water-shed is 10,000 acres; that of the impounding reservoirs and filter-beds 549 acres, with a storage capacity of 3¼ billion gallons. The ordinary work of the six filter-beds is 14 million gallons daily.

The materials used for filtration are: 2½ feet sharp river sand, clean gravel of the following depths and sizes: 6 inches ⅛-inch diameter, 6 inches ¼-inch diameter, 6 inches ½-inch diameter, 6 inches 1-inch diameter, and 6 inches 2-inch diameter; 6 inches of broken stone 4-inch diameter, and 12 inches broken stone 6-inch diameter. The cost of filtration is $1.37 per million gallons. The water, after filtration, flows from the clear water tank through a main, 44 inches diameter and 18

miles in length, to the service reservoir at Prescott, 102 feet lower than the clear water tank; to break the pressure in this length there are two small reservoirs. From Prescott the line is continued by two pipes, one 44 inches and the other 36 inches in diameter, a distance of five miles to the service reservoirs, which are seven in number, with a water surface area of 37⅓ acres, and 114 million gallons capacity. They are partly above ground and covered. The quantity delivered through the conduit, is 10⅓ million gallons daily.

There are four pumping stations located at the respective wells, with five Cornish and five Bolton and Watts' condensing engines. Four pumping stations have been abandoned on account of the pollution in well water. Part of the town is supplied directly from mains and partly from cisterns. It is now compulsory for all new property to be provided with cisterns, and that the overflow-pipe be carried outside the premises instead of being connected to soil-pipe or sewer. A special staff of men is employed to make house-to-house inspection of all water fittings and appliances. The cost of the water-works was about 10 million dollars, and is inadequate. They are now constructing an artificial lake, 1 mile wide by 5 miles long, for impounding the waters of the Vyrnwy River in North Wales, 780 feet above the sea level, and 67 miles distant from the city. The area of water-shed is 22,000 acres. The dam will be a masonry structure, 120 feet extreme depth, and 100 feet wide at base; storage capacity, 1,900 million gallons. The cost is estimated at $15,000,000, and daily capacity 52 million gallons.

Glasgow.—The present water system was commenced in 1856, and completed in 1859, after the designs of Mr. J. F. Bateman, civil engineer. The supply is taken from Loch Katrine, including Lochs Drunkie and Vennachar, with a drainage area of 47,800 acres, and a storage capacity of 1,455 million cubic feet. The total length of aqueduct is 25¾ miles, of which 13 are tunneled, 3¾ of iron pipe across valleys, and remaining 9 miles of open cuttings and bridges. There are 80 distinct tunnels. The capacity of aqueduct is 50 million gallons per twenty-four hours. The amount required for compensation purposes is fixed

at 40½ million gallons daily, to be discharged into the River Teith. The cost of the works was 6 million dollars. The water is exceptionally soft, being less than one degree.

Manchester.—The new supply was commenced in 1848, designed by Mr. J. F. Bateman, civil engineer. The source is in the counties of Derby and Chester, 777 feet above city datum. There are thirteen storage and distributing reservoirs, with a water surface of 975½ acres, and capacity of 6,458 million gallons. The greatest depth of reservoirs is 84 feet. The conduit is 18 miles in length. The drainage area is 19,300 acres. Available daily supply is 33 million gallons, of which 13 millions are required for mill-owners. The average rain-fall is 50 inches, and mean available resource of 33 inches. The cost of the works was 4 million dollars. The population in 1874 was 750,000; daily average consumption 16 million gallons, and 550 miles of pipe.

Edinburgh derives its supply from springs and brooks flowing from the northern slope of the Pentland Mountains. The water is collected in storage reservoirs, with a capacity of 280 million cubic feet, three of which are compensating reservoirs for mill-owners. The conduit is 8 miles in length, and varies from 20 to 15 inches in diameter. The water is distributed directly into mains with an equalizing cistern on the Castle Hill, 225 feet below the source of supply, and 332 feet above tide. The capacity of pipe is 253 cubic feet per minute. There were three filter-beds (in 1868) a short distance below the reservoir embankment. The sand surface of each is 90 by 90 feet. The superficial area of the three filters, 24,300 square feet; maximum rate of filtration, 85½ U. S. gallons per square foot per diem. The spring water is not filtered. The additional works were completed in 1868, which increased the supply to 992 cubic feet per minute, or 10,685,770 U. S. gallons per day.

Dublin secures its water supply from the Vartry River, 24½ miles distant from city, and 692 feet above low water at Dublin. The area of water-shed is 14,084 acres; the storage capacity, 2,400 million gallons. The water is conveyed through a 33-inch cast-iron pipe (with an average fall of 20 feet to the mile) to the

Stillogram distributing reservoir. There are three receiving tanks on the line, with self-acting valves to shut off the water in case of pipe bursting. The distributing reservoirs contain 86 million gallons—are 230 feet above the average head of the city, and 4½ miles distant. Two 27-inch pipes distribute the water to the city from this point. There were seven filter-beds in 1875, each 215 feet and 115 feet at the top and 187 feet by 89 feet at the bottom, and 10 feet deep. The filtering material is 6½ feet deep, composed of 2½ feet 4-inch stone, 2 feet gravel, and 2½ feet washed sand. The head on filter-bed was increased from 2 to 3 feet to secure larger supply. The total cost of this new supply was 3 million dollars. The water-rate taxation is 26½d. per pound. The population in 1875 was 330,000; daily average consumption, 14 million gallons. All plumber fittings must be inspected and stamped, for which a fee of two cents is charged. This consumption, by careful inspection, was reduced from 19 millions. The largest annual rain-fall from 1861 to 1874 was 69.34 inches; minimum, 40.08 inches. Fifteen inches is allowed for evaporation, leaving 25 inches for available supply for the dryest year during this period.

Berlin.—The water department is owned by an English company, called the Berlin Water Company, who have had the exclusive privilege of supplying filtered water as required by the contracts since 1856. After 1881 the Government has the option of taking stock, and should the dividends exceed 10 per cent., one-half of the surplus is to go to the sewerage fund for the proposed sewers.

The water is derived mainly from the River Spree, through a canal reaching to the middle of the river. The pumping station is one mile outside of the city, in which are located eight double pumping engines, each pair having two beams, two pumps, and one fly-wheel. The first four engines erected have pump-barrels of unequal diameter and stroke, being respectively, 38 and 21½ inches diameter and 32 and 36 inches stroke. The large barrel was originally used for the delivery of the river water to the filter-beds under a pressure not exceeding 20 feet; the small barrel delivered the filtered water into

the city under a varying pressure of 90 to 120 feet. As now operated, the four oldest engines pump the river water into the settling or storage basin before filtration; while the other four deliver the filtered water directly into the city mains, but the pressure is regulated by a reservoir and stand-pipe alongside of it. The stand-pipe is double-legged, connected at four points, each connection having a valve, except the highest. The highest connection is 200 feet above the pump-house, the lowest about 115, with others intermediate. The water of the small reservoir, when full, stands at about 110 feet above the pump well. There were eleven filters in 1875, with an area of 400,000 square feet. During the summer only eight of the beds are used effectually. They are cleaned in winter every month, and every week in summer. One-half of the old sand is replaced each time of cleansing with new sand. The average rate of filtration is 90 gallons per square foot, and maximum rate 120 gallons per squre foot per twenty-four hours.

The filtering materials consist of 24 inches sharp sand, 3 inches of coarse sand, three courses, each 6 inches in depth, of gravel, of the size of a pea, hazelnut, and walnut, and 9 inches of granite pieces. The head of water on filter is 39 inches.

Frequently the river water is pumped directly into the filter-beds without subsidence. The stream is very sluggish in its velocity, being held back by locks for the purpose of navigation, the water does not carry sufficient sediment to render subsidence a necessity. There are, besides, certain lakes not far above the works through which the river flows, that are effective settling basins. They, however, communicate to the water a dark vegetable tinge.

The statistics for 1875 were: Population, 969,000; daily average consumption, 12¼ million gallons; number of meters, 6,916. Water-rent receipts, for 1875, were $600,000 or 13½ cents per thousand gallons, and expenses were $376,000, or 8 cents per thousand gallons.

The water rents are assessed upon the valuation of the property, with extra rates for additional water privileges.

New works were erected in 1875–'77, with a daily maximum

capacity of 12 million gallons. The source is the "*Tegeler See.*" The water is collected, by infiltration, in twenty-three cisterns, each having a separate connection to a suction-pipe, 36 inches diameter, 4,000 feet long, which leads to the pump wells, stationed midway on the suction line. The cisterns are circular in form, with two concentric walls, the first of stone, the second of brick, with an intervening space filled with gravel through which the water percolates. The interstices of the stone are small, to prevent the washing in of sand, in which the wells are made. The water is pumped, by six compound engines, into a reservoir of two compartments, whence it flows into a second pumping station at Charlottenburgh, where four compound engines raise the water a second time, with a lift of 125 feet, into two reservoirs of six million capacity. The water is then distributed into the city by two lines, one for the north side, the other for the south side of the city. The first pumping station is four miles from the second works, and the latter six miles from the city.

Vienna had a population, in 1875, of 1,007,365. Previous to the application of the new supply, in 1873, the city was supplied by ten thousand wells; ten gravitation works, for suburbs, public and private puildings, palaces, etc.; four pumping works—one for large abattoir, one for the parks, a special supply for the main street, called Ring Strasse, which cost $75,000, besides several small private works, and sixty-six public wells for street sprinkling, etc. The first pumping works was erected in 1843, by Emperor Ferdinand I., and given by him to the city. The total cost, to 1871, of this service, was nearly $1,200,000, consisting of three pumping engines, of Watts' & Wolf's designs, with a gross horse-power of 220; three reservoirs, and a suction and filter canal 27,000 feet long. The water is taken from a canal of the Danube, and raised forty-seven feet high. The daily delivery was 2,600,000 gallons. In 1864, fifteen projects for supplying the city with water were submitted, and the plan of securing the spring water from the foot of the Alps was adopted. Work was commenced in 1870, and completed in 1873. The cost was nearly $11,000,000. The mean quantity

secured daily from the springs was originally 37 millions, the maximum 45 millions, and minimum 5½ millions. The water is collected in three reservoirs, located on mountain ridges, with a capacity of one million gallons. The conduit is fifty miles long, and has sixteen tunnels, 5.2 miles long, drifted through rock and cemented, and nine and one-half miles of masonry bridges. The water is delivered into a reservoir, arched and covered with ground; from this it is led into three other covered reservoirs, with a combined capacity of seven millions. The quantity realized from the springs was not as large as expected, and additional springs were added to the source at an expense of $250,000. It is now the intention to increase the main pumping works for manufacturing purposes, so as to reduce the supply of spring water for domestic use.

Hamburg had a population, in 1875, of 337,602. The water-works were erected in 1849. The water is taken from the River Elbe, through an arched canal, to four pump wells (for subsidence of the water) with a combined capacity of 53 million gallons. The water is slightly turbid, except in floods. The pumping station is two miles above the city, and contains four Cornwall and one Wolf engine, with a total horse-power of 850. The water is forced through a stand-pipe 240 feet high, under a variable pressure, according to the demand, into the pipes. There are three reservoirs for equalizing the pressure, also storage of water. Two of them are stone structures; the other is a covered iron tank on a stone foundation 39⅓ feet high. The maximum consumption was 19 millions daily; and daily average, for 1875, was 15¼ millions, or 45 gallons per inhabitant. The cost of pumping one million gallons is $20, or $8.33 for one million gallons raised 100 feet high.

Frankfort-on-the-Main was supplied by well water. In 1872, a supply was brought into the city from the Spessart Mountains, where the water from 139 springs were gathered together, and conveyed through an aqueduct 41 miles long, two miles of which is made of cement 9½ to 18 inches in diameter, 38½ miles of 14½-inch cast-iron pipe, and ½ mile of canal. The water flows through a syphon tower. There are two reservoirs—one

of 3½ millions, and the other of .8 of a million capacity. The population, in 1875, was 103,136. Daily average consumption, 1¾ million gallons; miles of pipe, 64½.

Leipsic.—The water-works was built, by the city, in 1866, at a cost of $900,000. The water is taken from the Pleisse River, through an arched aqueduct, 656 feet long, to subsiding reservoirs or wells, two miles in diameter, and thirteen feet below the lowest stage in the river. The water is pumped into a reservoir, 140 feet lift, by two Wolf engines, with a power of 120 horse-power. The maximum daily consumption of water, in 1876, was 2.6 millions, and the minimum was 1.8 million gallons.

Stuttgart had a population, in 1875, of 107,575. It has two kinds of supply—one for drinking, that of spring water, and the other for manufacturing and general use. For the latter demands, the supply is taken partly from the Neckar River, and pumped through three artificial filter beds; and partly from lakes, whose water is conducted, through cast-iron pipes 15,000 feet in length, to five filter-beds, and thence into two reservoirs, 145 feet below the lake. The reservoir, for the filtered water from the river, is three miles from the pumping station, and 180 feet elevation. Seven million gallons are used daily.

The spring water is conducted through 23.6 miles of pipe, into a reservoir of 132,010 gallons capacity. The maximum daily consumption of spring water, in 1875, was 580,800 gallons, and minimum consumption 369,600 gallons.

Dresden.—The water-works were erected, in 1875, at a cost of $2,000,000. The available maximum delivery was 11.88 million gallons per day. The water is taken from the Elbe River, through two cast-iron pipes, 9.8 feet below low water, and conveyed to two wells, 23 feet in diameter, dug along-side of the river. The water is pumped, by six double engines, with 720 horse-power, through 3,608 feet of pipe, into a reservoir 197 feet above the pumping station. The maximum daily consumption of water, in 1875, was 3.7 million gallons, and minimum .7 of a million; population, 197,000. In 1876 there were 2,047 meters in use.

Marseilles obtains its water supply from the Durance River, at a point sixty-two miles from the city. The water is con-

veyed through an open canal (excepting the numerous tunnels) with a fall of six inches per mile. Thirty-four millions, of the 159¾ millions total daily ordinary flow of the canal, is considered sufficient for the city, the balance being available for irrigation and water-power, while the waste flows into the sea. About one-seventh of the water, as estimated, is lost by evaporation and filtration. There were five settling basins, with a water surface of 220 acres, constructed along the line of the canal, designed to increase the depurition of the heavier particles of sediment by diminishing the velocity of the water. Only one of these basins was serviceable in 1868. The largest one was used for a short period only, because of a defect in the construction of the dam; the others were abandoned because of the neglect in or difficulty of withdrawing the sediment. A costly filter gallery was built at Longchamp, consisting of two apartments, with a series of arches in the center, forming the bed for the filtering material and the cover for the collecting reservoir for the filtered water. The plan was abandoned in 1866, because of the unusual amount of sediment carried down by the Durance River, which is estimated at one thousandth part of its volume. In 1868, there were from three to four inches of compact mud on the sand beds, and the gallery used for a reservoir only. Subsiding basins have since been constructed. The rate of filtration, when the gallery was in operation, was 90 cubic feet to the square foot, equal to 8,312,940 U. S. gallons per day for both filter-beds, or 36 gallons per inhabitant for a population of 230,000.

Paris.—Previous to the introduction of the Vanne supply, in 1865, the city was supplied from the following sources:

	CUBIC FEET.
1. Aqueduct of Arcueil, 10 miles long, built in 1620–24.	56,480
2. Canal de l'Ourcq, 60 miles long, from the River Ourcq, built in 1801–22	3,671,200
3. Pumping works at Challiot, from the Seine River..	1,421,000
4. Pumping works at Quai d'Austerlitz, opp. Challiot.	28,240
5. Artesian well of Grenelle	31,770
6. Springs on the north side of Paris, and of the Pres. St. Gervais	17,650
Total	5,217,340

or 39,025,713 gallons per day for 1,600,000 persons, or 25 gallons per head.

The Passey artesian well increased the supply 5½ millions. The Vanne supply has, as its source, the rivers Dhuys and Vanne. The conduit is 83 miles long; its capacity 20 millions daily.

There are projected works (1876) to secure the waters of the Mame that will increase the daily supply 25 millions.

The waters are generally very impure, chiefly obtained from navigable streams. None of the water is filtered. There are two covered reservoirs—Ménilmontant and Moutrouge—of vaulted arches, after the Roman style. The pumping works are located in the city. The daily average consumption, in 1868, was 55,-861,472 gallons, or 33 gallons per head. Water is distributed throughout Paris, but not more than one-fifth of the houses have water connection. The others are supplied in carts and buckets, carried by men to the door. About 7,000 men, principally natives of Auvergne, are employed thusly. It is a custom to let the water run for three hours, from the public fountains, in the morning to cleanse the streets.

Bombay.—The water-works were commenced in 1856. The source is in the valley of the Goper, where the Vehar impounding reservoir, with a storage capacity of 12,900 million gallons is located. The maximum depth of the reservoir is 80 feet, with an area of 1,394 acres. There are three dams—one 835, one 555, and the other 936 feet long. The extreme height of first dam is 84 feet, inner slope 3 to 1, and the outer 2½ to 1. The embankments were made in layers of six inches. The top width of this dam, which carries a roadway, is 24 feet. The puddle walls are 10 feet wide at the top, and have a batter of 1 in 8 on each side. The trenches, for the foundations, were excavated into the solid basalt below the surface rock. The slopes and tops of all the embankments are covered with stone pitching 12 inches in depth, with another 12 inches of broken stone underneath. The waste weir is 358 feet long, with a top width of 20 feet.

CHAPTER VI.

The succeeding articles, viz.:

1. The Geology of Hamilton County;
2. Our subterranean water resources and well-boring;
3. The adjacent water-sheds in Ohio;
4. Kirkwood's survey for a water supply—1865;
5. The Ohio River;
6. Scowden's survey for a water supply—1872;
7. Moore's survey for a water supply—1882;

have been prepared expressly for the dissemination of that information bearing upon the proposed new water supply, that will be useful, as well as interesting, to the citizens of Cincinnati at this particular time. These subjects have their respective bearing on our water supply,—that of the geological structure being especially important, because we learn from it a more accurate knowledge of our subterranean resources; of the impossibility of infiltration of the Ohio River waters, and of the formation and availability of our water-sheds.

No. 1.

GEOLOGY.

(Arranged from the Ohio State Geological Reports, 1873.)

The rocks of Ohio are:

SYSTEM.	GROUP.	STRATA.	THICKNESS IN FEET.
Quaternary.	Drift.	Delta sand. Forest bed. Erie clay.	200
Carboniferous.	Coal. Measures.	Upper coal measure. Barren " Lower coal measure.	1,200
	Conglomerate.	Conglomerate.	100
	Lower carb. Limestone.	Chester limestone.	20
	Waverly. Group.	Cuyahoga shale. Berea grit. Bedford shale. Cleveland shale.	500
Devonian.	Erie.	Erie shale.	400
	Huron.	Huron shale.	300
	Hamilton.		20
	Corniferous.	Sandusky limestone. Columbus "	100
	Oriskany.	Oriskany sandstone.	10
Upper Silurian.	Helderburg.	Water lime.	100
	Salina.	Salina shale.	40
	Niagara.	Hillsboro sandstone. 30 Niagara limestone. 180 Niagara shale. 60 Dayton " 5	275
	Clinton.		50
	Medina.		20
Lower Silurian.	Cincinnati.	Lebanon beds. Eden shales. Mt. Pleasant beds.	1,000
	Calciferous.	Calciferous Sand rock.	475
	Potsdam.	Potsdam sandstone.	300

The oldest rocks are designated by Eozoic system, consisting of Laurentian and Huronian groups, and are metamorphic rocks underlying a broad belt in Canada, from Labrador to the Lake of the Woods, and thence to the Arctic Sea. It is computed that this group of strata attains a thickness of 47,000 feet in Canada.

The Potsdam sandstone, the first member of the Silurian system, rests unconformably on the Eozoic rocks wherever the two are found in contact. This, as its name implies, is a sandstone, and is the first product of the invasion of the Eozoic continent by the ancient ocean, and the action of the shore waves upon the cliffs and surface.

It has been reached in the deep borings made at Columbus, Louisville, and St. Louis. Neither the Eozoic or Potsdam stones are exposed in any part of Ohio. Resting on the Potsdam stone, is a formation called calciferous sand-rock, so named in New York because there it consists of a mixture of lime and sand. This formation holds the lead of central and eastern Missouri.

Trenton limestone, with its underlying strata of chazy, Black River, and bird's-eye limestones, rests on the calciferous sand-rock, and forms a calcareous mass of 300 to 600 feet in thickness. It is exposed in New York, Canada, Lake Superior, and Upper Mississippi, where one of its members, the Galena limestone, claims special notice as being the repository of all that rupture.

Upon the Trenton rests the Hudson group, consisting of the Hudson River and Utica slates, and composed of mixed calcareous and argillaceous sediments. This group is regarded as an equivalent to the blue limestones, or Cincinnati group, which are of special interest to the inhabitants of Ohio, inasmuch as they are the lowest rocks exposed within our territory.

These older rocks are brought to the surface by an axis of upheaval, reaching from Nashville to Lake Erie. They have been still further exposed by the cutting down of the valley of the Ohio, near Cincinnati, where 800 feet of the series are exposed to view. The wells on the upper Cumberland, in Kentucky, were sunk in rocks of the Hudson age. The earthy lime-

stones of the Hudson period indicate a shallowy and retreating sea, an approach to land conditions, and the completion of one circle of deposition.

The rocks next in order are:

The Oneida conglomerate marks a period of land subsidence, or water elevation. It is composed of coarse materials torn from the coast by shore waves. The system is found in central New York.

The Medina sandstone.—A period of mechanical sediments. In New York it is 300 to 400 feet in thickness. It has been struck in borings for oil in northern Ohio, but not well marked.

Clinton Group, in Ohio, is represented by a limestone 15 to 20 feet thick, an outcrop following the line of junction of the Lower and Upper Silurian.

Niagara Group is above the Clinton and occupies a wide-spread and more important formation, composed of equal masses of limestone and shale. This is the rock that underlies Chicago. The Niagara and Clinton overlie the Cincinnati Group.

Salina is the formation from which the salt is obtained at Syracuse. In northern Ohio it overlies the Niagara, and contains the gypsum of Sandusky. This deposition marks the era of a retiring sea, which left a series of shallow basins that became great evaporating pans.

Helderburg group is the surface rock of a large area in Ohio, and forms a summit of the Upper Silurian, and completes a circle of sedimentary formation corresponding, in a way, with that of the Lower Silurian.

The Trenton groups are nearly pure carbonate of lime, while those of the Niagara series—Clinton, Niagara, and Waterlime—are highly magnesian.

The Devonian age contains many strange forms of ancient life. In the Mississippi Valley, the Devonian strata are mostly calcareous, and much thinner than in New York and Pennsylvania, showing plainly that here, as in eastern Canada, open sea prevailed during this age, and that the Cincinnati Arch formed a land surface probably throughout all the Devonian ages. The Devonian system comprise:

Oriskany sandstones.

Corniferous limestone.—An open sea deposit. The average thick

ness in Ohio is 100 feet, and forms two belts of outcrop on opposite sides of the Cincinnati arch. The rock contains 20 per cent. of magnesia. Fragments of land plants and limbs of trees are found in this group.

Hamilton group.—A soft, blue limestone in Ohio.

Huron shale—exhibits a prevailing black color, and contains 10 per cent. of combustible matter. The line of its outcrop is marked by oil and gas springs. It is exposed in Kentucky and Tennessee, on both sides of Cincinnati anticlinal. It contains a large amount of carbon, derived from sea-weeds.

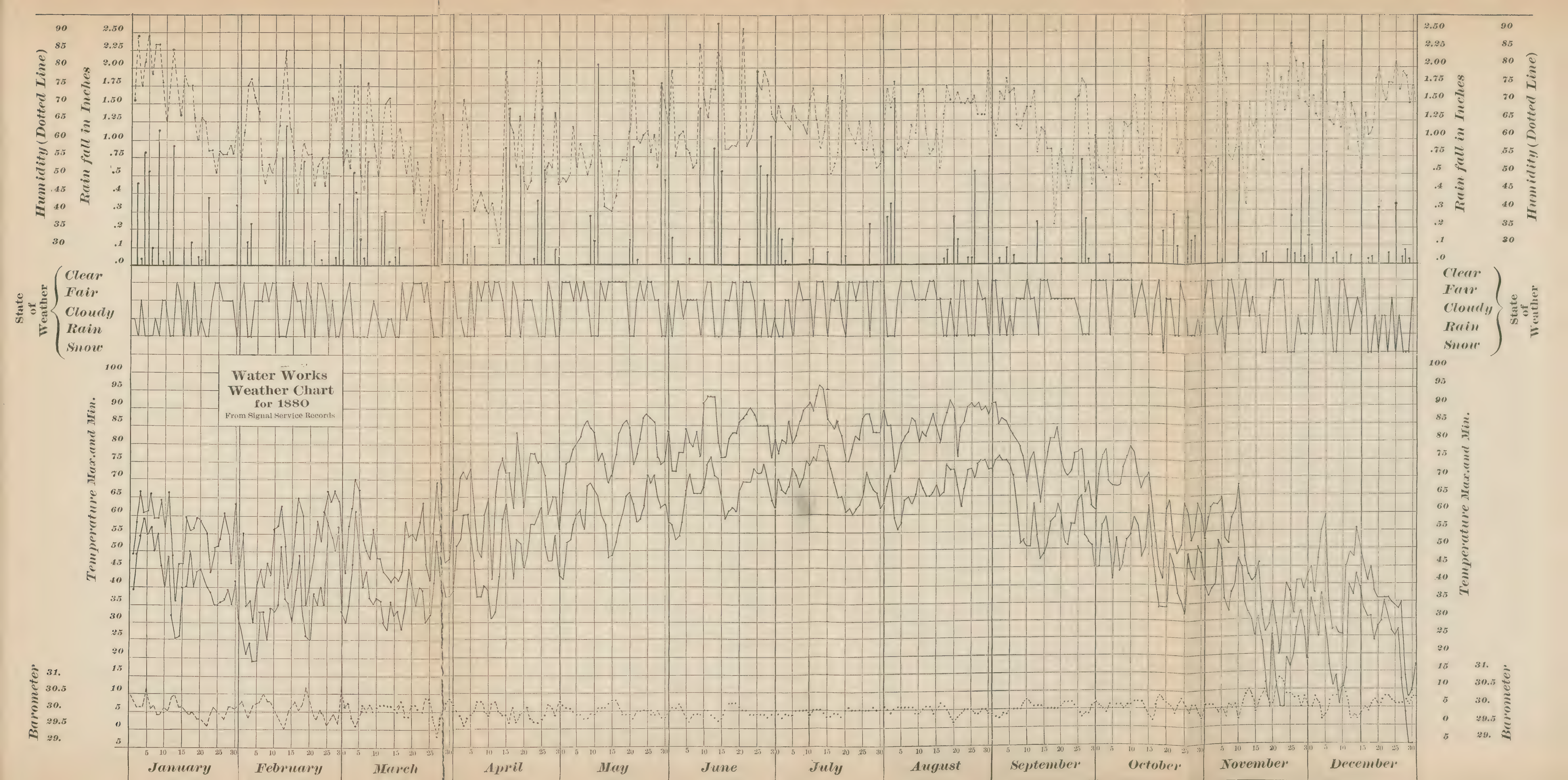
Erie shales is the name given to the Huron shale in northern Ohio and Lake Erie.

The carboniferous system is the highest group of rocks found in Ohio, and holds nearly all the beds of coal. As this period is not relative to Hamilton County, we shall only briefly refer to it.

At the period of the formation of the lowest bed of coal, the level of the carboniferous continent would seem to have been the highest; for when the stratum of bituminous matter had accumulated to the depth of a few feet, it was submerged by water, that brought shales and sandstone, and spread them in layers of many feet in thickness above it, before the requisite conditions were reached for the formation of another stratum. The intervals of repose, when the surface of the land was nearly at a level with the sea, were marked by the carbonaceous matter, and the thickness of each stratum measures the length of time during which this state of quiescence continued.

The changes of level were apparently all in one direction, that of submergence. During the epoch of the coal measure, the surface of the land and at the sea level, while the first stratum of coal was forming, was depressed until there had been deposited upon it a series of strata, which measured in Ohio, before being eroded, fully 2,000 feet in thickness, and included at least twelve workable seams of coal, with a great number of thinner ones.

At the time of the formation of the highest coal-beds, the Alleghany Mountain system was elevated, and an area including most of the States of our Union was raised above the ocean,


Water Works
Weather Chart
for 1880
From Signal Service Records
Humidity (Dotted Line)
Rain fall in Inches
State of Weather
Clear
Fair
Cloudy
Rain
Snow
Temperature Max. and Min.
Barometer
January
February
March
April
May
June
July
August
September
October
November
December

never again, to the present time, submerged. The anthracite coal basins of Pennsylvania were once a part of the Alleghany coal-field, but were isolated by the upheaval and erosion of the mountain ridges; and by this disturbance, all the rocks were more or less metamorphosed, and most of the volatile ingredients of the coal driven off, leaving it in the condition of anthracite.

THE DEPOSITS OF DRIFT.

The period immediately following the Tertiary age [but separated from it by we know not how many years] presents a complete change in the physical condition, that during this time the pervading warmth of the Tertiary was changed to an Arctic cold. While, in the former age, the climate of our Southern States was carried to Greenland; in the latter, or drift period, the present Greenland was brought as far south as the Ohio. This was when we had our icebergs or glacial age. The gravel, the bowlders, and an unstratified clay thickly studded with small fragments of rock, are the glacial surface-covering. Mingled with these are found many pebbles and bowlders of crystalline rock, such as are found north of the great lakes.

The finding of large bowlders in fields are the deposit of icebergs that once floated over our country. The glaziers reached as far as Cincinnati, planing, grinding down, smoothing all rock surfaces, and excavating the basins of our great lakes. The retreat of the glaciers left clay and bowlders and a great inland sea of fresh water, filling basins, before occupied by ice, 500 feet above the present surface of Lake Erie. At a later period, by continental elevation or the removal of barriers to drainage, the water level was gradually depressed until the inland sea was reduced to the comparative insignificance of our great lakes.

The descent of the water by motion of the waves, cut the well-marked terraces and edges.

CINCINNATI ANTICLINAL.

The term, Cincinnati Group, is now applied to the blue lime-

stone series, and is an equivalent, in the geological nomenclature, to the Hudson Group of New York.

Its thickness is estimated at 1,000 feet. The line of upheaval passes from the south line of Tennessee, with a direction a little east of north, through Cincinnati to Lake Erie. Throughout its whole length the strata are raised in a distinct arch, from which they dip away, on the one side under the Alleghany coalfield, on the other beneath the coal basin of Indiana and Illinois.

The bearing of this axis of elevation is nearly parallel with that of the folds of the Alleghanies; that the date of its upheaval was subsequent to the carboniferous, and anterior to the Triassic period. The line, north of Cincinnati, extends from the Ohio River in a direction a little east of north to the lake shore, between Sandusky and Toledo. In consequence of the erosion, which all the region bordering the Cincinnati Arch has suffered, the line of the axis presents no conspicuous topographical features. About Cincinnati the summit of the arch has been much more deeply and extensively removed than farther north, yet this is still higher than its northern prolongation.

There is every reason to believe, therefore, that this was originally the highest part of that portion of the arch within Ohio, and, in common with the Blue Grass district of Kentucky, the blue limestone area about Cincinnati is the most elevated portion of the ridge; that which has been the longest above the sea level and suffered most from surface erosion. We find here a line or tract from which the strata dipped on both sides in opposite directions.

The strata, that are found in the tops of the Cincinnati hills, can be followed to the eastern side of Brown County, where they seem to disappear beneath the river with a marked easterly dip; while below Cincinnati, near Madison, Indiana, the same beds are carried beneath the river by a strong westerly dip. The Cincinnati anticlinal, unlike the folds of the Appalachian system, generally has its longer slope to the westward, and its steeper descent towards the east, estimated at 35 feet per mile. In the western half of the State, and especially along the summit of the Cincinnati Arch, the dip of the strata is strongly

northward, amounting to about 1,000 feet between the Ohio and the lake. The surface of the Cincinnati Group is in Highland County, about 500 feet above Lake Erie, while on the lake shore it is nearly 400 feet below the lake. These figures do not represent the entire dip, inasmuch as the crown of the arch is extensively eroded where it crosses the Ohio in Clermont County. The Cincinnati section was originally crowned, there is little reason to doubt, with the Lebanon beds [the highest rocks of the Cincinnati group] in whole or in part, which suffered by erosion, forming our valleys of to-day.

The surface of the blue limestone, near Lebanon, is 441 feet above Lake Erie, while the same rocks were found in the Columbus well to be 721 feet below Lake Erie, a dip of 1,167 feet in a distance of about 70 miles by an air line, or 16.6 feet per mile.

Toward the northern extremity of the arch the dip is northwest and more rapid, the strata descending under the Michigan coal-field. Near the lake-shore the minimum dip is 20 feet to the mile, while on the Ohio it is 40 feet. The easterly dip is a succession of steps or waves beneath the trough of the Alleghany coal-field, the axis of which passes near or beyond our eastern border. This dip is so great that the lowest stratum exposed on the crown of the Cincinnati arch is on the eastern side of the State, buried about 2,000 feet beneath the surface. East of the Ohio all the rocks rise again, and not only the lowest exposed in our State, but even those which underlie them, crop out on the flanks and summits of the Alleghany Mountains. Along the Kentucky River from Frankfort to Nicholasville, and at Murfreesboro, Tennessee, the basal portion of the blue limestone series is exposed to view; and if it was originally as thick at these points as elsewhere, not less than 800 to 1,000 feet of the upper part have been removed.

HAMILTON COUNTY.

Strictly speaking there are no hills in Hamilton County, the surface being all referable to the tablelands and to the valleys

worn in them. The elevated lands, called hills, are merely isolated remnants of the old plateau, which have, thus far, escaped the long continued inundation. This isolation is effected by the Little Miami, the Ohio, the Millcreek Valleys, and the abandoned channel of the Great Miami.

The bedded rocks of the Cincinnati section are as follows:

Lebanon beds,	293 feet		
Cincinnati beds proper,	425 feet	Hill quarry beds,	125 feet
		Eden shales,	250 feet
		River quarry,	50 feet
Mt. Pleasant beds,	50 feet		
Total,	768 feet		

The Mt. Pleasant beds are so named because, at the Ohio River bed at this point, they are the lowest of the exposed beds, and underlie the lowest beds at Cincinnati by 50 feet. The Cincinnati beds have their inferior limit at low water of the Ohio, and for an upper boundary the highest stratum found in the Cincinnati hills. Their greatest elevation, above low water-mark, is 450 feet. The Eden, or middle shale, is so named because of its prominence in Eden Park hills. It has no economical value, indeed its relation to economical interests are mainly in the way of disadvantages to be overcome, because of its instable character. Of the 250 feet not more than one foot in ten is limestone, the remainder being shales, clay, or soapstones. These shales have scarcely tenacity enough to hold their place in steep descents, still less, when they have been removed from their original beds, can they be made to cohere, and they form treacherous foundations for buildings erected, or for roadways constructed upon them.

The strata of river quarry-beds are comparatively but little exposed. A moderate amount of building-stone of superior quality is taken from the Covington quarries. But little can be burned into lime, but the concretions constitute a hydraulic lime of great energy.

The Lebanon beds, in contrast to the Mt. Pleasant beds, are the highest of the Cincinnati group, and the location determine their name.

The drift formations are divided into—

1. Drift deposits of the highlands and slopes.
2. Drift deposits of the lowlands and valley drift-beds.

The upland drift has no uniformity in the order of formations aside from the monotonous deposits of yellow clay, which, when filled with water, becomes quicksand. But little clean gravel occurs in the upland, and bowlders also are unfrequent. The drift clays come largely from the waste of blue limestone effected by glacial attrition, while the natural soil has the same origin, except the work of disintegration has been done by the slow action of the atmosphere.

The lowland drift consists of the following terraces, in a descending order:

	FEET.
Soil	2 to 5
Gravel and sand with seams of loam,	40 to 60
Brick clay with sand and loam	20 to 30
Buried soil with trees, leaves, etc.,	5 to 10
Gravel and clay,	5 to 10
Total,	72 115

The gravel of the Ohio differs from the Miami in being largely composed of sandstone pebbles instead of limestone.

A formation of local occurrences, known as the blue or Springfield clay, is found in a few places, but in limited, vertical and horizontal, extent. The greatest thickness, of more than 30 feet, is found on north Pearl Street, above Pike.

The broad valley, now occupied in part by Millcreek, extending from the present valley of the Great Miami at Hamilton to the Clifton hills, just north of Cincinnati, separates into two branches, one passing to the north and east of the city, and entering the valley of the Little Miami between Red Bank station and Plainville, while the other branch is the present valley of the Millcreek. There are no rocky barriers (nothing, in fact, but the same drift terraces that make the walls of its present course) to shut out the Great Miami from entering the Ohio valley at the same points where the Little Miami and Millcreek enter. There is every reason to believe that this was once its course.

Another of the earlier courses of the Great Miami, is now occupied by the Dry Fork of the White Water; still a third of the old channels is found near Cleves, Miami Township, where the Miami approaches within one-half mile of the Ohio, but is blocked from entering it by a ridge 150 to 175 feet, composed of glacial drift, and instead makes a circuitous route of 10 miles for an outlet.

The well of Timothy Kirby, in Cumminsville, developed the following borings:

	FEET.
Soil and brick clay,	12
Sand,	4
Blue clay with gravel,	30
Gravel,	19
Coarse sand,	3
Sand, with fragments of bituminous coal,	11
Blue clay with gravel. (Low water of Ohio River.)	9
Blue clay—fine sand, sprinkled with coal,	16
Sand, water-worn gravel, blue clay, with occasional fragments of bituminous clay. Shales of blue limestone group	43
Total,	151

A remarkable feature of the Millcreek is here presented, of the present bed being at a higher level by 120 feet, than that of the ancient channel,—an erosion that could not have been effected under existing circumstances, but more probable, to the glacial period.

The coal-field wastes are also unaccountable.

No. 2.

OUR SUBTERRANEAN WATER RESOURCES.

Underlying our drift formation is that impervious strata of blue limestone, 1,000 feet in thickness, through which no water can circulate. The lowest limit of this mass of stone is at low water of the Ohio River, at Cincinnati, from which point it anticlines in all directions. There are crevices or pockets, however, in which water has been accidentally found. The following are examples:

NAME OF OWNER.	LOCATION.	FORMATION.	DEPTH IN FEET.	TOTAL DEPTH OF WELL IN FEET.	DIAMETER OF BORING IN INCHES.	WHERE WATER WAS FOUND.
		Blue clay.	25			
John Kaufman	Vine Street.	Sand and quicksand.	75			
		Blue clay.	55			
		Quicksand and gravel.	35			
		Limestone.	25	215	3½	In crevice.
		Soil and quicksand.	75			
Holder's Tannery........	Colerain Pike.	Clay.	90		3½	
		Limestone.	50	215		
		Alluvial and gravel.	80			
Freiburg & Workum....	Main Street.	Limestone.	170	250		In crevice.

The waters of the above wells are necessarily hard, although that at Holder's tannery is used for all purposes. The water at John Kaufman's is very turbid. The Freiburg & Workum well was originally a dug one, forty feet deep, but the quantity was insufficient. When they struck the present source, they destroyed the adjoining surface wells of Hoffheimer Bros.

A number of failures to secure water in this limestone formation is on record, but we can notice only a few.

At Rasche Bros., tannery, on Plum Street, opposite Bank Street, they drove a 6 inch well through, respectively, 16 feet of clay, 4 feet quicksand, 15 feet blue clay, 70 feet yellow clay, and solid quarry rock. A pump was then inserted but was inoperative on account of the large amount of sand. They continued the boring to 185 feet, striking clay and soapstone, but found no water, and abandoned the undertaking.

Wm. Kirkup & Son, Pearl and Ludlow, bored 60 feet into rock, for water, without success. At Maddox, Hobart & Co.'s rectifying establishment, they have pierced the rock 150 feet, but found no water up to this date. At Weber's brewery, on McMicken Avenue, an attempt was made to get water in the rock, and abandoned, after boring to a depth of 458 feet.

The Cincinnati group is about 1,000 feet in thickness of blue limestone, forming, almost exclusively, the rocks of Hamilton County, although an outcrop of the oil stratum has been struck in the wells of the Cincinnati Coffin Company and White Mills Distillery. At the former establishment, flowing gas was found

at a depth of 82 feet. Another well was started, and at the same depth gas was discovered. The boring of the latter was then continued into the rock to the depth of 168 feet, when water was found. The water was analyzed by Prof. Wayne with the following result:

	GRAINS IN EACH GALLON.
Chloride of Sodium	33.21
Chloride of Calcium	4.20
Chloride of Magnesia	1.17
Sulphate of Lime	10.64
Carbonate of Lime	26.64
Carbonate of Magnesia	3.15
Oxide of Iron	12

The gas burnt out in a few days.

White Mills Distillery has four wells, from 4 to 6 inches in diameter, and 220 to 235 feet in depth, bored through, respectively, 50 feet of clay, 40 feet clay and quicksand, and balance *soapstone* or shale and limestone, where water was found in a crevice, highly charged with gas and very brackish.

The following wells secure their water from drift terraces:

OWNER.	LOCATION.	FORMATION.	DEPTH IN FEET.	TOTAL DEPTH IN FEET.	SIZE OF BORE IN INCHES.	REMARKS.
Hulsman	W. S. John, near Lib'ty.	Fill.	30			
		Blue clay. Quicksand. Gravel.	131	161	4	Bored to the rock.
Windisch, Muhlhauser & Co.	Brewery on the Canal	Sand. Quicksand.			4½	Driven to the rock.
		Gravel Sand.		180	4½	
John Hauck	Brewery on Dayton St.	Quicksand, yellow. " blue.		170		
		Gravel.	46			
Emery Hotel	Vine St. bet. 4th and 5th.	Blue clay. Black mud. Quicksand.	40			
		Gravel.	60	146	3	From the cellar.
W. W. Johnson	Sycamore & Yeatman.	Alluvial.	12			
		Gravel.	68	80	3½	To the rock.
City Infirmary	Hartwell.	Black loam.	12			
		Blue clay.	13½			
		Blue clay mixed with gravel.	6½			
		Bowlder gravel.	15			
		Quicksand.	15			
		Gravel.	29	92	3½	Also another well 73 feet.

Upon the limestone lays the drift, consisting of water-worn pebbles, gravel, sand, and clay. The porous nature of this formation, with the assistance of a level surface plain, absorbs a very large percentage of the rain-fall, and produces a fertile subterranean water supply, whose depth varies from 30 to 200 feet.

There are in this vicinity about 250 wells that secure the water from this source. The water is strongly impregnated with iron and magnesia—a ferruginous decomposition from the fossil drift-wood found in this formation. The availability of these wells is in proportion to the capacity of the respective pumps attached to them, but their combined requirements have had no apparent effect, at present, on the source. Yet the fact can not be disputed, that this drift supply of water is a very limited one.

The practical experience in London and Liverpool substantiate the above fact, for there the underground sources have been materially lessened by the demands made upon them, notwithstanding they are the richest resources of this nature, and vastly superior to ours.

Prof. Orton, of the Ohio Agricultural College, in a valuable paper on the "Relations of Geology to the Water Supply of the Country," refers to the purity of the drift water in the south-western part of the State. He says: "The broad and fertile terraces of the river valleys constitute, especially in the south-western corner of the State (Ohio), the most attractive and most valuable portion of its area. They consist of sand and gravel in large measures, and to this structure they owe their chief attraction. *But this same structure renders them unfit to be used for the water supply of the towns built upon them;* for, although an abundance of clear and sparkling water can easily be reached, it must not only be looked upon with suspicion, but must be positively condemned as unsafe.

"These gravel-beds are as porous as a sieve, and there is indisputable proof of the free communication of the water sheet and all the receptacles of impurity that the surface of the ground contains. The only relief is found in the fact that the water sheet is also in free communication with the rivers, ris-

ing and falling with them; *but* even *this* does not free the wells from the poisonous effects of the filth soakage from above. Geology turns over to sanitary science the conclusion, that the drift wells of central and south-western Ohio are, in all densely populated districts, small cities, towns, villages, and hamlets—even in those containing no more than a dozen houses—*utterly unfit for human use.*"

The above facts are applicable to all the drift formation, including that portion protected from immediate filth soakage of blue clay formation.

A recent examination of our sewerage system, by the U. S. Census Bureau, developed the fact that Cincinnati is polluting its subterraneous soil, to an alarming degree. by the vault system. That no city has so neglected the sanitary necessity of tapping the sewers for house drainage than Cincinnati; that this nature of carelessness was the cause of Memphis' sad fate, which we have escaped because our soil is of sand and gravel, and susceptible of natural drainage. Yet through this same soil passes the water that is used by some 250 well-owners, still the use of this water is increasing.

London was originally supplied by shallow wells in gravel-beds of 10 to 20 feet in depth, and the direction of its growth was controlled by this water-bearing strata, until the establishment of the New River Water Company in 1600. The Public Health Act of 1872 gives the sanitary authorities power to close these wells.

ARTESIAN WELLS.

Beneath the Cincinnati group are the calciferous sand-rock and Potsdam sandstone, which are porous and water bearing, but they rise to the surface nowhere in our State. They have been reached, however, at this point in several of the deep well-borings, and flowing water of sulpho-saline nature was found, at the following locations:

NAME OF OWNER.	LOCATION.	DEPTH IN FEET.	SIZE OF BORE IN INCHES.	PRESSURE IN LBS.	TEMPERATURE.	CAPACITY PER HOUR IN GALLONS.
Rabe's Distillery........	Cumminsville.	1,400	$4\frac{1}{2}$	35		6,000
Millcreek "	West of Millcreek.	1,440	$4\frac{1}{2}$	45		16,000
Cincinnati Gas Co......	West Front Street.	1,360	$4\frac{1}{2}$	41	60	8,300
" "	" " "	1,360	$4\frac{1}{2}$	40	60	8,300
" "	Eastern Avenue.	1,475	6	52	61	30,000
Moerlein's Brewery......	North Elm Street.	2,408	4		62	24,000
Keck's Fertilizing Works..	Cumminsville,	1,380			60	

Through the kindness of Gen. A. Hickenlooper, President of the Cincinnati Gas Company, the following complete account of the borings at their works on Front Street is given, which will also serve for a description of the above artesian wells.

The depth and classification of strata are:

Filling.................	5 feet.	Limestone, very hard	15 feet.
Yellow clay..........	5 "	Red sandstone.......	62 "
Blue clay..............	20 "	White sandstone.....	85 "
Sand and gravel.....	90 "	Coarse sandstone Coarse limestone.	15 "
Soapstone	3 "	Sandstone	140 "
Blue limestone.......	40 "	Very hard, flinty limestone. Red and white marble. White marble or flint	25 "
Blue & gray limestone	50 "		
Sandstone	5 "		
Limestone	380 "		
White limestone......	240 "		
Sandstone............	65 "		

Total... 1,250 feet.

The synopsis of boring is condensed as follows:

July 24, 1880.—The contractor, John J. Pfeffer, drove a 6-inch iron tube with a heavy sinker, a few feet at a time, through 123 feet of drift, into limestone. A sand-pump was used to remove the loose formation. This portion was completed August 2d, 11 A. M.

August 2.—Commenced drilling a $4\frac{1}{2}$-inch hole through the stone formation at an average rate of 33 feet per 24 hours, and continued to a depth of 425 feet, when the diameter of the hole was reduced to $4\frac{3}{8}$ inches. The drilling was then continued, at the rate of 29 feet per 24 hours, until the 28th of August, when the socket pulled out of pole attached to sinker at bottom of well, and at the same moment

the top pole, attached to chain on drilling beam, broke and fell into the well along-side of the sinker. This accident was repaired September 7th, and drilling resumed. at rate of 20 feet per 24 hours, until a depth of 1,025 feet was reached, October 11, 1880, when the drill broke. Resumed work, at rate of 12 feet per 24 hours, until November 5, 1880, when a depth of 1,265 feet was reached. At the depth of 1,225 feet, the well was tested by sinking a 4-inch pipe into the well with a bag at lower end to fit tightly into the 4½-inch bore. When the pipe reached a depth of 15 feet below the 6-inch tubing, the water flowed over the top of the pipe at surface, showing a leak around the bottom of the pipe where it was bedded in the rock.

November 8th.—Tested well, and found a pressure of 30 lbs. per square inch, and a flow of 90 gallons of water per minute.

February 17, 1881.—When testing well No. 2, the gauge was placed on this one, which showed only 15 lbs. The bore was then increased to 4½ inches, and drilling continued to a depth of 1,360 feet, the last 40 feet being only 3½ inches in diameter. The additional 125 feet was through alternate formations of sand and limestone; the last 10 feet through a hard flinty formation. Boring into this last formation increased the pressure to 41 lbs., and the flow to 200,000 gallons per day. The outlay of the two wells is placed at $8,000.

The analysis of the Moerlein artesian well, by Prof. Wayne, gave the following results:

	GRAINS IN ONE U. S. GALLON.
Carbonate of Lime	19.34
Carbonate of Magnesia	9.13
Chloride of Sodium	534.77
Chloride of Potassium	3.95
Chloride of Magnesia	17.26
Chloride of Calcuim	22.19
Sulphate of Lime	29.20
Sulphate of Potash	2.30
Iodide of Magnesium	30
Bromide of Magnesium	39
Oxide of Iron	43
Phosphate of Soda	1.34
Silica	79
Loss in analysis	76
Total	642.16

Prof. Newberry is of the opinion that soft water is improbable in these deep rocks.

No. 3.

WATER-SHED.

The courses of our streams show at a glance that a water-shed crosses the State from north-east to south-west. This water-shed forms a range of highlands that slope by long and easy descent to the Ohio in the south, more rapidly to the lake in the north. *This water-shed in its relief is almost insignificant*, its average attitude being only 500 feet above the lake, its highest point rising perhaps 1,000 feet above the bottom valley of the Ohio. Our topographical features may therefore be described of a plain, slightly raised along a line traversing it from north-east to south-west.

The following altitudes will show the topography of the northern divide. The levels are all above Lake Erie:

SURVEY OF DAYTON AND MICHIGAN R.R.	FEET.	MIAMI CANAL.	FEET.
Cincinnati—below lake,	67	Junction, Paulding County,	147.25
		Lock 27.	182.25
Hamilton,	29	Delphos, Lock 23. Allen Coounty,	211.
Dayton,	180		
Dayton Canal,	166	Spencerville, Lock 15. Allen County,	274.
Troy,	270		
Piqua,	360	Lock 13. St. Marys, Auglaize County,	291.25
Sidney,	428	Lock 10. " "	313,
Principal Summit.	430	Lock 9. " "	319.
Wapakoneta,	318	Lock 4. " "	361.
Lima,	302	Lock 3. " "	367.50
Cairo,	241	Lock 1. Bremen Summit, Auglaize Co.,	386.30
Weston,	103	Near Sidney,	376.00
	....	Troy.	257.00
Perryshurgh,	64	D. & M. R.R. crossing Dayton.	166.00
Toledo,	12	Basin at Hamilton.	37.00
	....	Upper level of canal at Cincinnati.	23.00
	....	Low water in Ohio River, below lake,	133.

The actual crest of the divide forms a singularly tortuous line with remarkable variations of altitude. The water-sheds, with which we are particularly interested, are found in the counties of Shelby, Mercer, and Auglaize, where we have the water-gap of the head-waters of the St. Marys and Auglaize, as feeders of the

Maumee River with the Wabash and Big Beaver Rivers on one side, and the Great Miami on this side; with another gap, between the Miami and Mad Rivers, and the Scioto River, found in Logan and Hardin Counties, in which the highest points of the State are found viz., 1,000 feet above low water in the Ohio River. These streams descend very rapidly to the level plateau (500 feet above the Ohio River) passing over lime and magnesia rocks, through swampy lands and "cat-head prairies," the latter composed largely of vegetable accumulations. The population, through which the Great Miami and Mad rivers flow, is approximately 360,000.

The available resources of the Big Beaver, Wabash, and St. Mary's water-sheds are collected in St. Mary's Reservoir, a lake of 47,000 acres, for feeding the Miami Canal north; while Lake Laramie in Shelby County, and Lewistown Reservoir in Logan County gather the waters of the Miami, and being at the summit level, feed the canal both north and south. This level is 519 feet above low water in Ohio River, St. Marys 424 feet, Eden Park Reservoir at Cincinnati 235 feet, and Third Street Reservoir 173 feet. The distance in air line from Cincinnati to St. Marys is about 95 miles, to Lewistown over 100 miles.

The waters of all the streams named present those features that experience considers most objectionable for a gravity supply, namely:

"1st. In the calcareous nature of the soil, producing hardness of water.

"2d. In the low and level plateau of water-sheds from which a minimum surface flow can be realized, requiring storage reservoirs of large surface area, that are objectionable, because; 1. The loss of water by evaporation: and 2. The liability to stagnation of water and propagation of vegetation.

"3d. The streams are fed by the drainage from richly manured farms, and the water polluted by vegetation of the swampy lands, and the sewage of a large and growing population. This condition is intensified, when we consider the proportional size of the streams to the amount of pollution, and the fact that the most perfect means of filtration would not suffice to make the water wholesome.

"4th. The available resources of these water-sheds are now used

for feeding the Miami Canal, from which a number of mill-owners secure their power, whose rights must be protected.

"5th. The insufficient elevation of the sources for securing a fair hydrostatic water pressure, and their extreme distance, causing loss of head by long conduit, and enormous cost for construction, for conveying unwholesome water."

RIPARIAN RIGHTS.

The compensation to millers by the Manchester and Liverpool Water-Works was fixed by Parliament at one third of the available rain-fall. Nearly one-half of the present capacity of the Glasgow supply is used by mill-owners.

On this subject John W. Erwin, resident engineer of the Ohio State Board of Public Works, says:

"The riparian right of water-users are great, and could not be purchased for $2,000,000. The water for this purpose can not be spared. The canal is fed as far as Middletown, by a feeder from Mad River. At Middletown we feed it from the Miami, which furnishes its supply of water to Cincinnati, a distance of forty-four miles. The Middletown Hydraulic Company have owned their rights since 1808, long before the canal was constructed; and when the canal was built there was no surrender cf such right, merely common consent to the use of the water, but since that time more than double the amount of water is used than was contemplated.

"By taking water to Cincinnati from the river, you injure the power supplied by the river at all points between Middletown and Cincinnati, and you would find great objections raised by users of power along the canal. The power derived from the canal is the life-blood of the town of Middletown, and of the mills along its banks—at Excello, Woodsdale, Rockdale, Hamilton, Rialto, Port Union, Crescentville, Lockland, and other places. The mills have large interests, and would not surrender their rights without a struggle.

"A large portion of the water of the Miami, and at the present time we might say half the volume of the water of the river is carried into Cincinnati by the canal. This is more than was ever contemplated, and is destined to injure the water-power of the river itself."

The abandonment of the canal in the city, will no doubt be

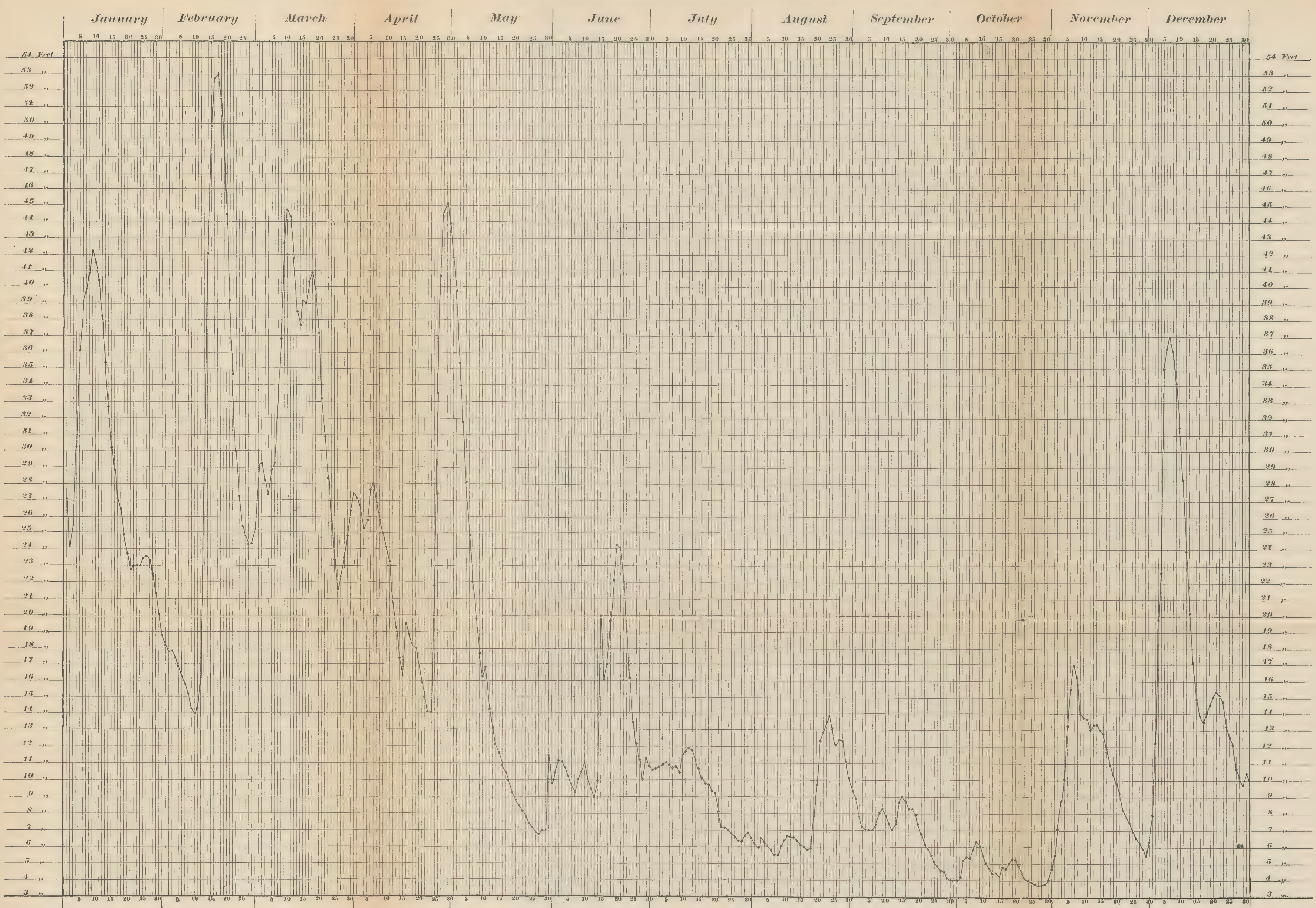
accomplished within a short time, when provisions should be made to provide a better use for this surplus water than turning it into Millcreek.

Monthly and annual quantity of water from rain and snow reduced to water, in inches and hundredths, at Cincinnati, Ohio. Latitude 39° 6′ north, longitude 84° 29′ west.

YEARS.	JANUARY.	FEBRUARY.	MARCH.	APRIL.	MAY.	JUNE.	JULY.	AUGUST.	SEPTEMBER.	OCTOBER.	NOVEMBER.	DECEMBER.	SUM OF THE YEAR.
1856	1.	2.49	1.51	.73	1.23	2.24	3.43	.61	3.62	1.74	2.09	2.19	22.88
1857	.54	1.98	.76	2.73	5.53	3.09	2.50	2.92	.75	4.92	5.36	3.82	34.90
1858	2.50	1.74	1.05	4.34	8.32	5.69	3.01	7.97	.85	4.66	2.57	6.41	49.17
1859	2.58	5.92	4.38	7.53	2.32	3.22	1.74	3.79	2.10	1.28	4.46	3.75	42.57
1860	1.43	1.56	.41	5.32	3.68	1.55	7.97	.92	4.34	1.28	3.53	1.85	33.84
1861	2.68	1.81	2.08	3.88	5.91	3.80	3.62	7.10	2.93	3.77	3.62	1.10	41.30
1862	4.74	2.36	5.84	6.30	3.32	3.02	3.05	1.49	.93	.80	3.97	3.01	38.83
1863	5.55	3.05	4.37	2.13	2.84	3.11	3.21	2.99	3.10	3.85	2.05	3.80	40.05
1864	1.85	.99	.90	2.43	2.34	3.43	1.25	3.42	8.66	2.92	3.40	2.94	34.51
1865	2.45	2.43	4.40	3.89	7.72	2.59	7.77	2.26	5.76	.86	.56	3.89	44.53
1866	2.74	1.26	5.06	2.03	.94	4.44	6.94	2.75	1.055	1.85	3.06	1.98	43.60
1867	1.41	3.56	2.71	2.74	3.80	3.73	1.60	1.57	0.47	2.05	2.20	3.07	28.91
1868	3.72	.57	4.87	2.72	6.09	5.60	1.21	4.64	7.19	1.32	1.70	2.07	41.60
1869	1.60	2.51	5.06	2.87	5.93	3.60	5.36	1.20	3.20	2.75	3.30	2.46	39.84
1870	5.35	1.55	3.26	1.59	1.74	4.84	2.38	0.58	.30	2.77	1.50	2.17	28.03
1871	2.34	3.53	3.57	1.23	4.66	2.02	4.30	5.22	1.08	.98	3.40	3.31	35.64
1872	3.118	4.18	2.438	4.890	4.362	3.442	7.129	2.191	3.170	2.852	.868	5.55	35.433
1873	2.808	3.717	1.90	2.098	3.856	3.291	3.935	4.766	2.340	3.212	2.521	6.843	41.193
1874	3.95	5.91	3.65	4.06	1.38	2.58	3.42	1.03	2.33	1.31	5.35	2.58	37.55
1875	1.59	1.83	3.69	2.12	3.92	4.83	9.63	3.17	.65	3.05	4.35	3.75	42.58
1876	9.49	2.92	5.07	3.26	1.25	6.53	6.91	6.38	3.17	4.26	2.36	.88	52.48
1877	2.33	.67	5.47	2.32	1.26	5.24	4.25	2.26	1.66	1.85	3.49	3.35	34.65
1878	4.33	2.33	4.03	3.05	2.53	5.03	4.32	4.11	2.84	2.39	2.77	3.89	41.62
1879	2.20	2.22	5.30	2.14	4.23	5.22	2.75	1.172	4.01	.65	4.05	7.11	51.60
1880	5.14	4.50	4.15	5.82	5.70	9.86	2.46	4.01	1.37	2.98	4.42	4.26	54.67
1881	3.76	4.95	3.51	3.25	2.23	7.82	3.12	.76	2.10	6.01	4.06	5.67	47.24

1856 to 1871 the observations were taken by Prof. G. W. Harper; 1872 to 1874 by the City Water-Works, and the last years by the Signal Service.

DAILY STAGE OF THE OHIO RIVER FOR 1880.



No. 4.

KIRKWOOD'S SURVEY.

In 1865 the common council appointed a special commission to investigate and report upon the best method of obtaining an abundant supply of pure and wholesome water. The committee consisted of L. A. Harris, mayor; Thos. H. Weasner, president of council; D. T. Woodrow, Henry Pearce, and Henry Kessler, trustees of water-works, Geo. F. Davis, Wm. P. Wiltsee, and Chas. Brown, who succeeded R. B. Moore, members of council; and A. W. Gilbert, city engineer. They secured the services of the most eminent of engineers, John P. Kirkwood, of New York. His instructions were to ascertain the most economical and practical mode of supplying pure water, either from the gathering grounds by gravity, or by pumping from the Ohio River. No scheme was to be considered that would not provide at least thirty millions daily, with resources for future necessities. This limitation rejected Lick Run and Ross Run entering Millcreek; West Fork and East Branch of Millcreek, Duck Creek and Sycamore Creek entering Little Miami River. Those that presented *fair* prospects for the collection of water as regards quantity were:

	Situation at connecting point.		Drainage area, sq. miles.	Degrees of hardness in U. S. gallons.	Remarks.
	Elevation above low water at Cincinnati, feet.	Distance from Cincinnati, miles.			
I. The great Miami Valley—	....	....	....	....	
Clear Creek	270	49	3[illegible].9	15.51	
Gregory Creek	220	38	16	13 31	after boiling.
Dick's Creek, below Middletown, was found	....	....	....	....	
to be very unfavorable for reservoirs	....	....	....	....	
II. Little Miami Valley—	....	....	....	....	
Muddy Creek	222	32	10.25	9 83	
Turtle Creek	220	33	27	11.35	
III. Valley of Millcreek—	....	....	....	....	
West branch of Millcreek	196	16	28.5	9.17	

The objections to these waters were: 1. The hardness; 2. The contamination of richly manured farms; 3. The uncertainty of the availability of the water-sheds. To produce the thirty millions it required the combined area of Clear and Gregory creeks, besides large storage reservoirs for dry seasons. The distance of latter creek is 38 miles from the city, and 15 feet below flow-line of Eden Reservoir.

He considered the waters of the Ohio most preferable *providing the water was taken above the city limits.* The plan embraced a pumping service with two lifts, to be located in Pendleton, with storage and settling reservoirs and filter-beds. The elevation of reservoir was 200 feet above low water, and would not supply elevations above 175 feet. The estimates were:

Three settling reservoirs,	$381,436.02
Two filter-beds,	514,220.50
Storage reservoir of 39 acres,	635,386.50
Pumping house and foundations for low service works,	194,822.80
Pumping house and foundations for high service works,	77,285.75
Pnmping engines—two for low service and two for high service, 30 millions capacity,	402,500,00
Force-main, with river inlets,	119,979.50
Forty-two-inch supply main to Third Street Reservoir	457,355.00
Lands and damages, etc.,	105,225.00
Auxiliary pumping engine and reservoir for Walnut Hills,	150,000.00
Total,	$3,038,214.07

The majority of the committee in recommending the plan stated; "that they regarded the question, as to the source of supply, as definitely settled for all time, that the Ohio River is the only means from whence this city should derive her supply of water." The site is as high up the river as can well be obtained without crossing the Little Miami." This latter consideration they thought would be demanded fifty or one hundred years hence. The minority report recommended the retaining of the present system, and the construction of a new reservoir in Eden Park,—the minority report was adopted. Had the Eden Reservoir been completed within a reasonable period it

would have served the purpose intended, at least for a few years, but before it was ready for use the consumption of water increased from five to seventeen millions daily.

No. 5.

OHIO RIVER.

The Ohio River above Cincinnati has a water-shed area, estimated by U. S. Census Bureau, of 100,000 square miles, one-tenth of which is of limestone formation. The hardness of the water varies in proportion to the contribution from this formation. The water, at the mouth of the Big Sandy, is .8 of a degree hardness; at Markley Farm, 4½ to 8; at Dayton sand-beach, 7 to 8; at pump-works, 6 to 8; Eden reservoir, 7 to 9; Eggleston Avenue sewer, 7 to 13; wells in the banks of the river at Dayton sand-beach, 32 to 39; and those at Sedamsville 50 to 60 degrees. The well water is upland surface water. In fact, all borings in the banks of the river secure, in more or less degree, this nature of water.

In the south-western part of this State, the river flows over the bedded rocks of the Cincinnati group, its waters alternately impinging on one side of its banks, and depositing its earthy matters, through the influence of sluggish currents and eddies, on the opposite side, and forming what might be termed accidental beds, as in the case of the Dayton sand-beach. The material deposited is an argillaceous substance; and, with the friction and influence of the water, is partly transformed into quicksand. The beds do not form a part of the river in low water, as depicted by the sketch in the last report of the Board of Health.

The sediment in the Mississippi water, at St. Louis, is nearly two per cent. of the bulk of the water; the largest portion (944 in 1,000) depositing itself within 24 hours. The Ohio River water, at this point, is, at times, almost as bad. The sediment forms a tenacious and impervious clay, so susceptible of solidification that conductors of river water are only kept open by a constant flow of water.

The volume of water passing down the Ohio River is an extremely variable one. No special gauging, however, has ever been made to ascertain the quality; but from the surface velocities, measured by the Chief Engineer of the Southern Railway, we can approximately arrive at the figures

At	3-foot	stage,	by	Water-Works	mark,	the	velocity	was	.97	miles	per	hour.
"	6 "	"	"	"	"	"	"	"	1.125	"	"	"
"	18 "	"	"	"	"	"	"	"	3.51	"	"	"
"	21 "	"	"	"	"	"	"	"	3.20	"	"	"
"	27 "	"	"	"	"	"	"	"	4.70	"	"	"
"	31 "	"	"	"	"	"	"	"	4.30	"	"	"
"	41 "	"	"	"	"	"	"	"	5.002	"	"	"

The slope of water surface, from water-works to bridge, was .367 of a foot for low stage; for average stage, .403 of a foot; and .415 of a foot per mile for high stage. The approximate flow of water in cubic feet per second at the Southern Railway Bridge is 5,000 feet for minimum stage, 100,000 feet for mean stage, and 400,000 for maximum stage. The minimum flow of the Schuylkill is 378 cubic feet per second; the Delaware, 2,000 cubic feet; the Merrimack, 2,100 cubic feet; and the Thames River, 700 cubic feet.

Investigations of the influence on our climate, by the removal of the forests, develop the fact that streams, utilized for water-power, have become less constant in their flow than formerly. The Ohio River has of late years exhibited greater fluctuations of levels than ever known, and has lost its prestige as a reliable channel of navigation. Prof. Newburg, in Vol. I of the Geological Survey of Ohio, records an instant where a large rock, at Smith's Ferry, has recently become so fully exposed that on its surface inscriptions were found, that are ascribed to a race which once populated this country anterior to the nomadic Indians.

There are about 78 villages and towns and 13 cities on the Ohio River between Cincinnati and Pittsburgh, a distance of 460 miles. The population on this portion of the river, and its contributing streams, is over 3½ millions. The average population, per square mile of drainage area, on the Ohio River is 47;

above Cincinnati, 35; on the Great Miami, 109; on the Delaware, 176; on the Hudson, 172; on the Merrimack, 92½; on the Susquehanna, 62; on the Connecticut, 78; on the Potomac, 54; on the Schuylkill, 45; on the Thames, above water-works, 300.

Considerable space has been devoted to River Pollution, to which attention is directed. The following remarks, however, afford comparative results for the Ohio River.

The comparative merits of river waters, as expressed in analytic results of pounds of sewage in each million gallons, are, for the Ohio water at Dayton sand-beach, .82; at Markley Farm, 1.00; at the pumping works, 1.81; at Eden reservoir, 1.78; at Eggleston Avenue sewer, 4.41; the Croton water, New York, .98; Glasgow, Scotland, water, .65; Thames River, 4.91; London supply, 1.33; Fresh pond, Cambridge, Massachusetts, 1.50; Mystic River, Boston, 1.87; Schuylkill River, Philadelphia, 1.58; Merrimack, above Lowell, .93; above Lawrence, .90; below Lawrence, 1.03.

The Thames and Lea Rivers have been condemned by the Rivers Pollution Commission because, as they say, there is no hope of remedying their disgusting condition, notwithstanding the parliamentary laws for their protection against pollution.

The Schuylkill River is the principal source of supply for Philadelphia, but its water is very suspicious. Above Reading, it is unfit for manufacturing and culinary purposes, owing to the large amount of sulphuric acid. This acid is, however, neutralized and considerably reduced before the water reaches Philadelphia. The Fairmount pool is polluted by cess-pool and slaughter-house drainage. The following means to restore and maintain the purity of the Schuylkill water has been suggested by Dr. Cresson:

1. The diversion of all sewage, now flowing into the pool of Fairmount dam, into another channel.

2. The diversion of all sewage, containing fœcal and animal matter, flowing into the river below Flat Rock.

3. The filtration of the sewage from all mills, to exclude solid matter, animal or vegetable.

4. The exclusion of ammonia waste and surface wash from gas-works, cemeteries, etc.

5. The cultivation of fish and of suitable plant life in and upon the waters of the river.

6. The erection of suitable cascades over the reservoirs, so as to secure the benefits of aeration to as great extent as possible.

7. The employment of proper prophylactic and curative agents as occasion may require.

Boston obtained legislative power to protect Pegan Brook from sewage pollution. Test cases, to compel manufacturers to provide some other means of disposing of their drainage, were carried to the Supreme Court, and decided in favor of the city. Similar cases will be brought against other offenders. In the meantime the pollution continues. The same authorities procured a law to protect Mystic Lake, and provide other channels for sewage. The provisions of the act were held to be impracticable, and the law is now a dead letter.

The self-purification of river water is not recognized by some authorities, but equally good authorities value its merits. The following observations on this subject are particularly applicable to Cincinnati:

"The most efficacious means to get rid of the sewage is not to put it into the river at all.

"A chemist can tell you the amount of organic matter contained in the water, but that covers an infinite variety of matters. He has no means of discrimination as to what is really the ferment—the infectious material—of cholera from a great number of other organic matters.

"The question is, not whether the chemist would find out the organic matter, so much as it is, whether the germs that disseminate the disease still have their property further down the river. This can only be solved by the effects. *You might go on using the water for years, and it might not be discovered until some outbreak of disease occurs directly attributable to the water.*"

The practical sanitary experiment would then be solved, but at the expense of a number of lives.

Dr. Klob, of Vienna, has discovered, in the evacuations of cholera patients, millions and millions of microscopic fungi similar in form to a mushroom.

There are, above the Cincinnati pumping works, six sewers discharging their filth into the Ohio River, besides the fœcal drainage of no less than five thousand privies, all within a radius of less than three miles. Now, the quality of such water is readily established, for we are putting the sewage into the water knowing there are no means to get rid of it.

OHIO RIVER STATEMENT, SHOWING THE HIGHEST, LOWEST, AMD AVERAGE STAGES FOR EACH YEAR AT CINCINNATI WATER-WORKS.

YEAR.	HIGHEST STAGE.			LOWEST STAGE.			AVERAGE FOR THE YEAR.	
	DATE.	FEET.	IN.	DATE.	FEET.	IN.	FEET.	IN.
1832	February 18	62	11½					
1847	December 17	62	3½					
1858	June 16	43	10	October 3d.	2	5	12	10
1859	February 22d	55	5	September 19th,	3	3	17	7
1860	April 16th	49	2	October 3d	5	4	16	
1861	April 19th	49	5	July 13th	5	1	19	1
1862	January 24th	57	4	October 31st	2	4	17	5
1863	March 12th	42	9	October 6th	2	6	15	
1864	December 23d	45	1	August 6th	3	1	16	8
1865	March 7th	56	3	October 19th	5	8	21	10
1866	September 26	42	6	August 17th	4	9	19	2
1867	March 14	55	8	October 19th.	3		17	
1868	March 30th	48	3	July 21st	5	1	18	8
1869	April 2d	48	9	August 21st	5	4	19	8
1870	January 19th.	55	3	October 4th	3	10	17	10
1871	May 13th	40	6	October 12th	2	8	11	10
1872	April 13th	41	9	October 14th	3		11	8
1873	December 18th	44	5	October 1 th	3	8	18	5
1874	January 11th	47	11	September 22d	[illegible]	4	15	8
1875	August 6th	55	4	September 19th	4	3	18	9
1876	January 29th	51	9	September 4th	6	[illegible]	18	2
1877	January 20th	53	9	October 9th	3	3	15	
1878	December 15th,	41	4	October 24th	4	4	16	9
1879	December 27th,	42	9	October 23d	2	6	14	6
1880	February 17th	53	2	October 28th	3	9	17	
1881	February 16th	50	7	September 18th	1	11	16	11

A recent examination of the currents of the river passing the inlets was conclusive that the Eggleston Avenue sewer, 1,000 feet below, could have no effect on our water supply. Be this as it may, its proximity taxes our delicate tastes. The location

of the inlet of the Shield aqueduct is not a desirable one, being at the revetment wall, past which all the shore water flows. The small aqueduct certainly can not be improved, its inlet being sixty feet beyond the wall, where the currents produce the best water obtainable.

The value of changing the location of the intakes can be illustrated to a good advantage by the experience of London during the cholera epidemic of 1854. After the epidemic of 1849, the Lambeth Water Company moved their intakes to Teddington, beyond the range of London sewage; while their competitor, the Southwark Company, continued to take its water close to one of the sewers. Their respective water-pipes interlaced each other; and of the 26,000 houses supplied by the Lambeth Company, there were only 294 deaths in 1854, while in 40,000 houses, supplied by the other company, there were 2,284 deaths.

SCOWDEN'S SURVEY OF MARKLEY FARM.

On the 29th of April, 1871, the Trustees of Water-Works, in response to the Council, submitted a report to them upon the necessity of a new water supply. On the ensuing 9th of June, the Council ordered that a competent engineer be employed to examine sites, and report upon the most suitable location for water-works, with plans, estimates of cost, etc. Mr. T. R. Scowden was accordingly appointed; and, on the 9th of September of the same year, he submitted a supplemental report, recommending, in the highest terms, the "Markley Farm" site. Upon his recommendation, the property was purchased for the sum of $22,321.50, consisting of 146 acres, with a river frontage of 2,000 feet. The principal points upon which the recommendation was based were:

"The site known as Markley Farm is a point where the water of the Ohio River is deep and free from drainage or any other vitiating influence to affect its quality, perhaps for a century to come, if ever. The shore is bold, and, with the bed of the

river, is of gravel and rock formation, washed clean by an active current at all seasons of the year. Pumping works may be located at this point without any objectionable and expensive inlet-pipe; while the adjacent hills afford an excellent site for a storage reservoir, 307 feet above extreme low water, and 75 feet above the Garden of Eden Reservoir. On the lower level there is a fine plateau for locating, not only the pumping house, but subsiding reservoirs and filtering basins.

"The force-main extending from the pump house to the storage reservoir will be short, or about 1,450 feet long, whereas, works located on the second site, or any other sites examined, would require force mains several thousand feet in length. By the first site, water from the river would be lifted by the pumps and forced to the reservoir with the least amount of power, friction, and expense of fuel to do the work. This site also commands an excellent and safe landing for boats supplying the works with coal.

"The analyses of waters lately taken at the Water-Works and at the Markley Farm clearly indicate the superior quality, purity, and healthfulness of the latter.

"It has been suggested that the offal from one or more distilleries, said to be in operation at New Richmond, some ten miles above the Markley Farm, would leave its taint in the water reaching the latter point. My answer is, that in this case the river, so slightly affected at New Richmond, and flowing ten miles to reach the Markley Farm, would, from agitation and dilution, and from the well-known self-purifying property of water, become pure."

Regarding the other sites surveyed he said:

"The second, but objectionable, site for water-works was found some three miles above the Garden of Eden reservoir, and about the same distance below the mouth and offensive discharge of the Little Miami River. This location, although favorable in many respects, intercepts the drainage of the upper portion of the city, and all of that from the Miami Val-

ley emptied into the Ohio River, which renders that cite wholly inadmissible for water-works purposes.

"The valley of the Miami forms a water-shed of several hundred square miles in area. Upon the surface of this vast plain is deposited the dead carcasses of animals, and the droppings from cattle of all kinds. The ground is covered with decayed vegetable matter, and the soaking of stable-yards, hog-pens, slaughter-houses, distilleries, stagnant pools, etc. The refuse is washed off by rain storms into the Miami, which is the common receptacle, and thence into the Ohio River.

"It is only necessary, first, to disease the water, then disease the man; and it is clear, therefore, that water-works located below the Miami would, by wholesale pollution, disease the whole community.

"There is no city in the civilized world so regardless of the cleanliness and health of its citizens as to adopt a plan of water supply to foist upon them the concentrated filth from sewerage and the impurities of a stream, the water of which is only fit for mill-power, manufacturing purposes, and for cattle to drink; and I did not think that Cincinnati was emulous of setting the example.

"With regard to intermediate points between the county line and the mouth of the Little Miami River, I found the Ohio River lined with sand-bars, some of which projected from the shore nearly to the middle of the river, miles in length; while the bottom or bed of the river was, for the most part, covered with logs and craggy stones."

His plan embraced the construction of pumping works for raising the water, first, from the river into subsiding and filter reservoirs, and then pumping it a second time into storage reservoirs. The water was to flow, through $10\frac{1}{3}$ miles of 42-inch supply mains, into Eden Reservoir. The capacity of the pumps was estimated at 60 millions daily. The recapitulation of cost was:

For Engine-House and Grounds.....	$312,790.00	
For Pumping Engines..................	750,000.00	
For Force Mains........................	92,130.00	
For Storage Reservoirs................	521,529.45	
For Subsiding Reservoirs.............	560,252.00	
For Clear-Water Well..................	14,669.60	
For principal Supply Main, two lines.	1,811,078.00	
Miscellaneous expenses...............	60,500.00	
		4,131,949.05
Add ten per cent...........................		413,194.90
Total cost..................................		$4,545,143.95

In conclusion, he said:

"I, therefore, regard the first and best site, known as the Markley Farm, as one commanding all the advantages sought, where works may be erected combining greater simplicity of construction, economy of cost, and maintenance when put in operation, than could be built at any of the other points mentioned."

No. 7.

MOORE'S SURVEY.

On the 23d of January, 1882, Mr. A. G. Moore, Superintendent of the Cincinnati Water-Works, submitted a communication to the Board of Public Works relative to the present condition of the pumping works and its future requirements. From it we arrange the following:

"The present pumps are deficient; that during the summer of 1881 the daily demands exceeded, at times, their capacity; and on one particular day there was a deficiency of over six million gallons. The engines are generally of light construction, and not sufficient for any increased loads. They are expensive in operation and maintenance. First-class engines of to-day would save two-thirds of the fuel used. The principal reliance, during the summer, is the large "Shield" engine, which is most extravagant on fuel, and has a wrought-iron

force-main, of weak material, intrenched 35 feet below the surface of the street. Some of the boilers are of an age that require them to be treated with the greatest care, and should be condemned. The principal buildings do not afford protection or access to the pumps in case of derangement during average high water. The hill-top service is inadequate, and a larger and more comprehensive system should be adopted for the supply of the increasing territory.

"The subject of increasing capacity requires immediate attention; and should the removal of the works be deemed inadvisable, it will become essential to at once proceed with the erection of machinery, buildings, aqueduct, and aqua-fort at the old works. The cost of these improvements is placed at $1,394,000; reserve engine for 1884, $618,000; and sewer in Front Street, to carry the sewage below the works, $1,600,000. Total, $3,612,000."

His plan for Markley Farm provides for one lift of 305 feet, with three compound pumping engines of 100 million capacity, subsiding and storage reservoirs, and one effluent-main 62 inches in diameter.

The estimate is condensed as follows:

Aqua-fort and buildings	$410,000.00
Engines and boilers for 100 million capacity	1,255,000.00
Three subsiding reservoirs of earth and masonry embankments, with 90 acres of water surface	1,836,500.00
Effluent-main, including 55,000 feet of 62-inch pipe, from the Farm to Eden Reservoir, and 18,000 feet of 48-inch, from Eden Reservoir to Harrison Avenue	1,804,000.00
Contingencies	460,000.00
Total	$5,725,000.00

The important question is presented by him, which the public must decide, namely, whether it is a prudent policy to expend four millions of dollars to improve the old works, and retain all the expensive and unreliable machinery, and still supply an impure and turbid water; or to expend an additional

two millions for an entire new system, from a source where a supply of pure and clear water can be secured, commensurate with the growing city.

He also embodies, by way of comparison, the following estimate for locating the works on the Kentucky side of the river:

For right of way and property, State and municipal..	500,000
Aqua-fort and buildings..	410,000
Three engines, with boilers complete	1,255,000
Subsiding Reservoirs..	1,836,000
Effluent-mains, 23,000 feet....................................	533,000
Tunnel for pumping main......................................	270,000
Tunnel under the Ohio River, 3,000 feet...............	825,000
Thirty-inch main to Eastern Avenue, 22,500 feet......	201,000
Contingencies...	550,000
Total for Newport plan..	$6,381,000

CHAPTER VII.

COST OF CONSTRUCTING WATER-WORKS.

The cost of constructing water-works varies very much, according to local features, geological structure, and kind of scheme most suitable to the place. In Great Britain, gravitation schemes cost from $10 to $13, and pumping schemes from $7 to $10, per inhabitant. The average cost per head, for London, was $20: for Liverpool, $20; for Bradford, England, $35; for Halifax, England, $25; for Dundee, Scotland, $30; for Glasgow, $15; for Manchester and Sheffield (each) $12 per head.

The average cost for a supply of 20 imperial gallons per day, per head, for 66 towns of Great Britain having gravitation supplies, was $8; for 48 towns, with pumping system, $5.80; and for 11 towns, having both systems, $7. From the annual report of Chicago, for 1880, we take the following cost, per capita, for water-works construction: Detroit, $23.11; Newark, N. J.,

$19.08; Wilmington, Del., $20.73; Buffalo, $18.29; Cincinnati, $26.20; Milwaukee, $19.25; Columbus, O., $18.14; Louisville, Ky., $25.04; Cleveland, O., $16.84; Providence, R. I., $52.74; Boston (gravity supply), $44.46; Manchester, N. H. (water pumping power), $24.24; Hartford, Conn. (gravity), $35.60; New York (gravity), $34.38, St. Louis, $26.07; Chicago, $17.49

The *Engineering News*, of New York, Vol. IX, No. 4, contains valuable tables on construction, and other valuable water-works statistics, from which the following is compiled:

Average cost of construction, per capita, for American cities having stand-pipe system, with 50,000 population, $20.70; for 30,000, $12; for 15,000, $16; for 10,000, $13,30.

Average cost of construction, per capita, for direct pumping system, for 75,000, $16; for 40,000, $13.40; for 25,000, $13.80; for 15,000, $21.70; for 10,000, $16.40; for 5,000, from $8 to $12.

Average cost of construction, per capita, for reservoir pumping system, for 100,000 population, $22.50; for 75,000, $21.50; for 50 000, $15.25; for 35,000, $22.50; for 25,000, $33.20; for 15,000, $22.40; for 10,000, from $10 to $32; for 5,000, from $8 to $40.

Average cost of construction, per capita, for gravitation works, for 50,000 population, $26; for 30,000, from $17 to $40; for 20,000, from $16 to $30; for 10,000, from $10 to $30; for 5,000, from $5 to $25; for 3,000. from $17 to $40.

REVENUE AND EXPENSE.

The average water-rent receipts, for 1880, per mile of water pipe in use, was $2,022 for Chicago, $3,200 for New York, $1,932 for Philadelphia, $2,730 for Boston, $3,307 for Brooklyn, $2,183 for Baltimore, $3,112 for St. Louis, $2,647 for Cincinnati, $1,600 for Louisville, $1,611 for Cleveland, $1,821 for Detroit, $2,060 for Buffalo, $1,500 for Milwaukee, $1,746 for Indianapolis; $1,128 for Columbus, Ohio, $3,556 for Pittsburgh, $397 for Washington, and $618 for Toledo, Ohio.

The cost of maintenance, for stand-pipe system, varies from 10 to 90 per cent. of revenue; for direct pumping, from 30 to 140 per cent. of revenue; for reservoir pumping, for large cities, from 12 to 37 per cent. of revenue; for small cities, from 12 to 120 per cent. of revenue; and new works, from 12 to 60 per cent. of revenue; for gravitation works, from 13 to 120 per cent. of revenue.

The revenue and the cost of maintenance (exclusive of interest), for each 1,000 gallons of water pumped, are respectively: Philadelphia, 5.77 and 1.28 cents; St. Louis, 6.91 and 2.55 cents; Chicago, 4.12 and 1.18 cents; Detroit, 4.09 and 82 cents; Buffalo, 3.50 and 1.00 cents; New York, 4.7 and one cent; Cleveland, 5.43 and 1.5 cents; Cincinnati, 7.01 and 2.6 cents.

The revenue received, for each 1,000 gallons delivered, is 15.52 cents at Liverpool, England; 14.35 cents at Berlin, Germany; 8.13 cents at Dresden, and 4 cents at Hamburg.

The comparative annual water-rent charges for a large house, in different cities, are as follows: Columbus, Ohio, $23.50; Lawrence, Mass., $20; Providence, R. I., $31; Brooklyn, $29.25; Buffalo, $43.50; Detroit, $23.25; Cincinnati, $28.73; Cleveland, $21.50; Chicago, $34; Philadelphia, $27.75; Pittsburgh, $71.50; Milwaukee, $34.50; Louisville, $51.50.

The meter rate charges, per 1,000 gallons, are 10 to 40 cents at Boston; 10 cents at Chicago; 10.2 at Cincinnati; 7 to 20 at Columbus, Ohio; 15 cents at Brooklyn; 13½ at Baltimore; 6 to 12 at Cleveland; 20 to 30 at Buffalo; 15 cents at Philadelphia; 7½ cents at New York; and 30 cents at Providence, Rhode Island.

The meter rates, per 1.000 U. S. gallons, at Stuggart, Germany, are 11 cents for filtered river water, 5½ cents for lake water, and 15 cents for spring water. The rates, at Frankfort-on-the-Main, are 3.7 to 5 cents; at Hamburg, Germany, 8½ cents; at Leipsic, 7½ to 9¼ cents; at Berlin, Germany, 6½ to 25½ cents; at Dublin, Ireland, 6½ to 11 cents; and at Glasgow, Scotland, 15 cents per 1,000 U. S. gallons,

The average dividend paid by the water companies of Great Britain, in 1870, was 7 per cent.

WATER PIPES.

The different kinds of water pipes in use are made of wood, cast-iron, wrought-iron, and glass. For adapting wrought pipe to practical use, various methods have been resorted to, that of coating with asphaltum, enameling, galvanizing, and lining inside and covering outside with cement. The latter method has been adopted by a number of water-works; but the liability to corrosion, from imperfect work and material, has caused its abandonment in a number of places. The Spring Valley Water Company, of San Francisco, have in use a number of wrought-iron riveted pipes, coated with asphaltum, of 20 to 42 inches in diameter. They are made of No. 12 to 14 iron (Birmingham wire gauge), and have a hydrostatic pressure upon them of from 200 to 400 feet. Virginia City (Nevada) water-works laid two lines of wrought-iron pipe across the Washoe Valley, 7½ miles wide—one of 12-inch riveted pipe, and the other of 10-inch enameled, lap-welded tubes. The pressure on the pipe at the bottom of the valley is 750 pounds. The enormous pressure has caused a number of rivets to give out. On the test for the respective capacities, the 10-inch pipe delivered 2½ millions per day, against two millions for the 12-inch pipe.

Hard water has but little effect on cast-iron pipe, due to the carbonates; but soft water attacks it so vigorously, that it not only gives a turbid appearance to the water, but seriously weakens the pipe by corrosion, and the consequent formation of concretions that reduce the capacity of the pipe. Hard water also causes the formation of lime deposits, that offer great impediments to the flow of water. These obstructions are now removed by boring tools forced through the pipe by the hydrostatic pressure. The Superintendent of the Halifax (N. S.) Water-Works records the cleansing of a 12-inch main, 32,000 feet long, in three-fourths of an hour. The preservation of cast-iron pipes, and the prevention of these concretions, are now accomplished by carefully dipping the pipe, previously

heated to a temperature of 300 degrees, in a bath of distilled coal tar, mixed, to a proper consistency, with linseed oil, or an oil of the tar.

The Rivers Pollution Commission condemned the common practice of using hemp in pipe joints, because it affords a nidus for the breeding, development, and decay of animalculæ. Turned joints were recommended.

The results of the observations of this commission prove conclusively than the commonly received opinion, that soft water necessarily acts upon lead pipes, is erroneous. The Loch Katrine water, which is notorious for dissolving lead in water exposed to the open air, yet no symptoms of lead poisoning have been discovered since its introduction, eighteen years ago. The water will act upon the lead at first, but will ultimately coat the inside of the pipe with a vegetable deposit that prevents further deterioration.

The frictional head, for a given diameter, is as the square of the velocity nearly; and, for different diameters, inversely as the diameters. Thus the loss of head, for each 100 feet of clean cast pipe, the velocity being three feet per second, is 1.35 feet for a 3-inch pipe; 1.02 for a 4-inch; .679 of a foot for a 6-inch; .407 of a foot for a 10-inch; .255 for a 16-inch, and .204 of a foot for a 20-inch pipe. The mean coefficient of friction, for cast-iron pipes of small size, with velocities of three feet, is .00644 for clean pipe; .0082 for slightly tuberculated pipes, and .012 for foul pipes.

WEIGHTS OF CAST-IRON PIPE,

WITH ALLOWANCE ADDED FOR BOWL AND SPIGOT ENDS.

Weights in columns per foot lineal. Iron .2604 per cubic inch.

Inter'l Diam. in inches.	Thickness of Iron Shell in Inches.													
	⅛	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1¾	2
2	3	6	9.3	14	19									
3	4	9	12.5	18	23									
4	5	11	16	23	30	37	44	53						
5	6.5	13	20	28	36	44	53	61						
6	8	15	24	33	43	52	63	72						
8	10	20	32.5	44	56	68	81	93						
10	14	26	40.5	56	69	84	99	114						
12	15	30	48	65	82	100	117	135						
14	18	36	54	75	95	115	137	159						
16	20	40	64	86	108	130	154	176						
20	26	52.5	79	107	134	162	190	216						
24	32	63	95	127	160	192	225	259						
30	40	78	118	158	198	238	278	318	358					
35	45	90	135	180	225	270	315	360	405	450	495	540		
36	47	94	141	188	235	282	335	384	433	483	533	583		
40	52	104	156	208	260	312	364	413	465	517	569	621		
42	55	110	165	221	276	331	386	442	496	552	608	662	718	
48	63	125	189	252	315	379	444	510	573	640	705	771	904	[illegible]

WATER-WORKS STATISTICS

FROM REPORTS FOR 1880 AND 1881.

Cities of U. S.	Miles of Pipe.	Population.	Gals. of Water per day per head.	No. of Taps.	No. of Meters.
Albany, N. Y.	77	90,903	55	2,832	10
Baltimore	524	332,190		49,000	524
Boston	500	412,000	87	69,504	1,631
Brooklyn	350	566,889	54	60,000	1,085
Buffalo	102	155,137	122	9,099	
Chicago	455	503,304	114	67,949	2,113
Cincinnati	196½	264,000	80	24,300	600
Cleveland	125	160,142	65	10,013	402
Columbus, O.	39	51,665	41	2,156	534
Detroit	209	116,342	127	22,465	29
Hartford, Conn.	71	42,553	119	4,291	
Indianapolis	43	75,074	40	1,200	12
Jersey City	323	120,728	122		220
Louisville	110	123,645	33	7,225	251
Milwaukee	86	115,578	75	6,835	
New York	510	1,206,590	80	80,000	550
Newark, N. J.	136	136,400	67	10,965	150
Philadelphia	746	846,984	67	110,000	30
Pittsburgh	112	156,381	102		
Providence	152	101,255	31	9,691	4,036
Rochester	113	89,363	56	7,588	100
San Francisco	220	233,956	70		
St. Louis	212	350,522	71	20,204	980
Washington, D. C.	175	147,307	176	17,000	

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